

PHENIX Muon Tracker Electronics in Year-1

Ming X. Liu

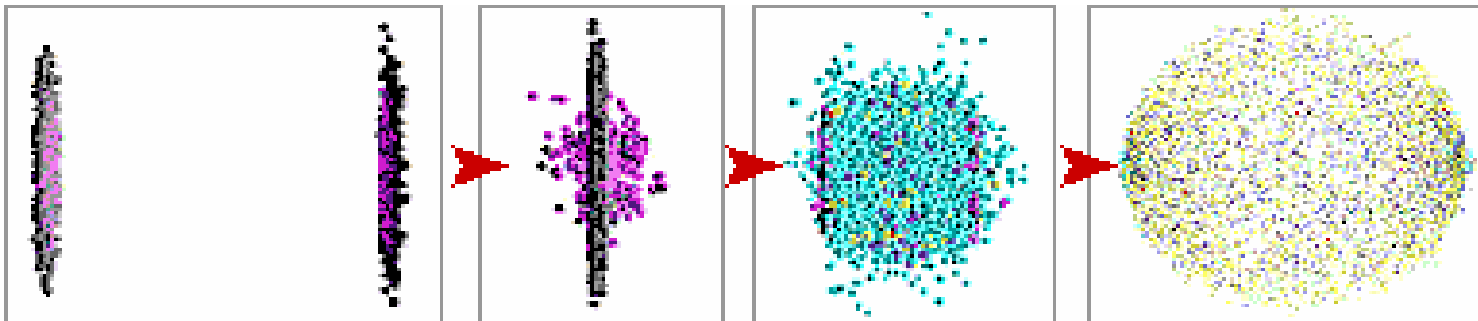
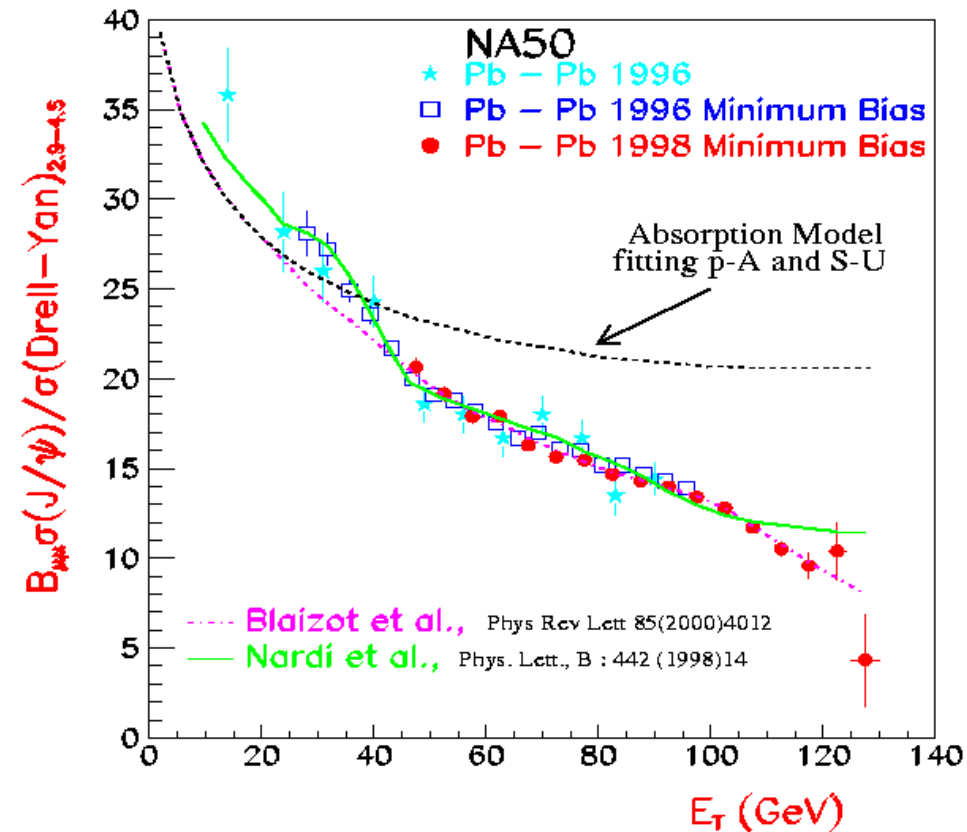
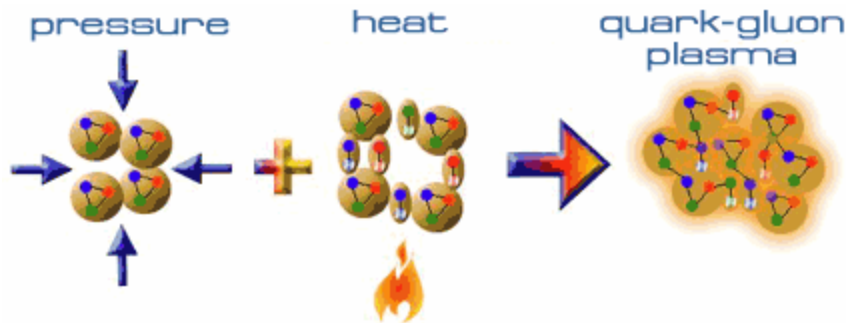
Los Alamos National Lab

- Phenix Experiment
- Muon Tracking System Design Specs
- Analog and Digital Design
- Results from RHIC Run-II

Physics - QGP?

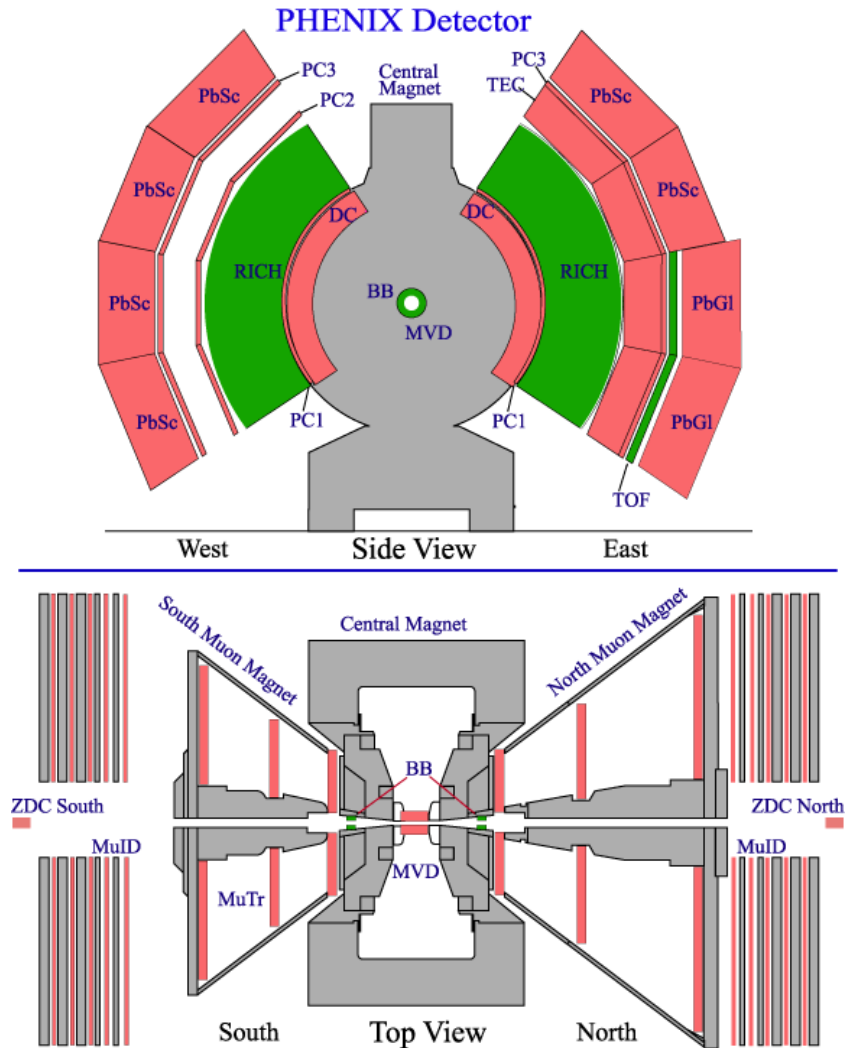
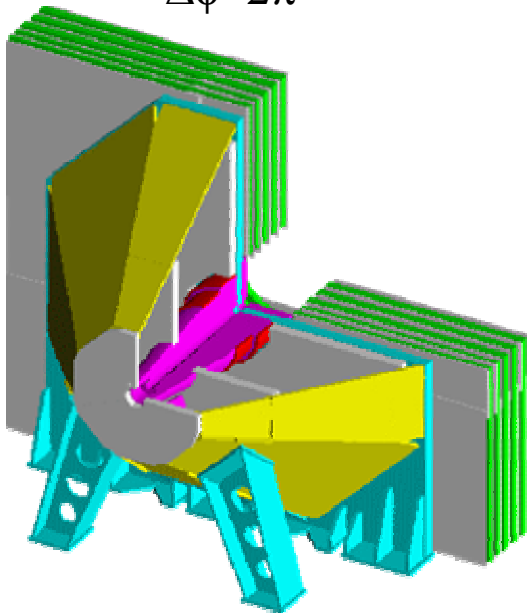
$$J/\psi(c\bar{c}) \rightarrow \mu^+ \mu^-$$

$$M_{J/\psi} = 3.1 \text{ GeV}$$



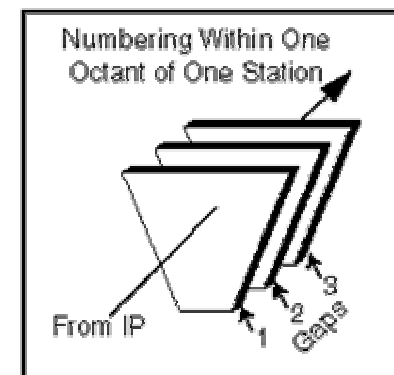
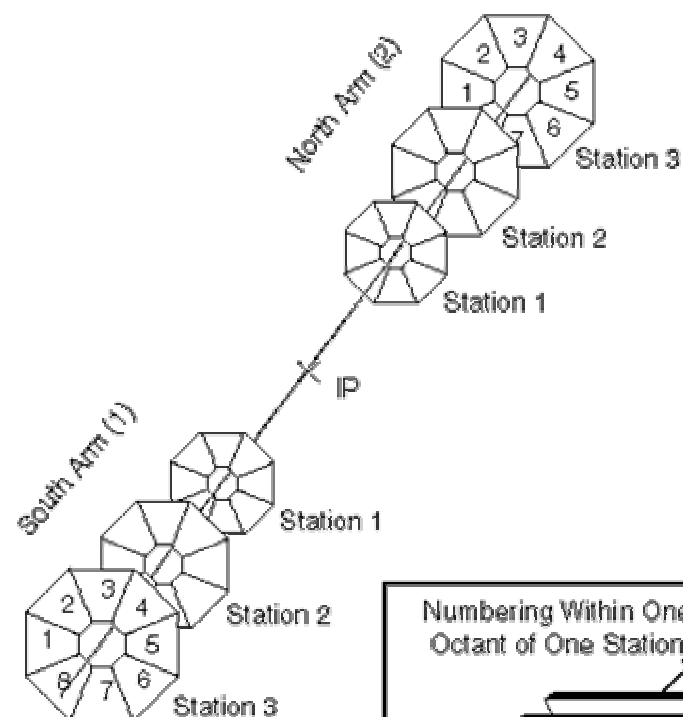
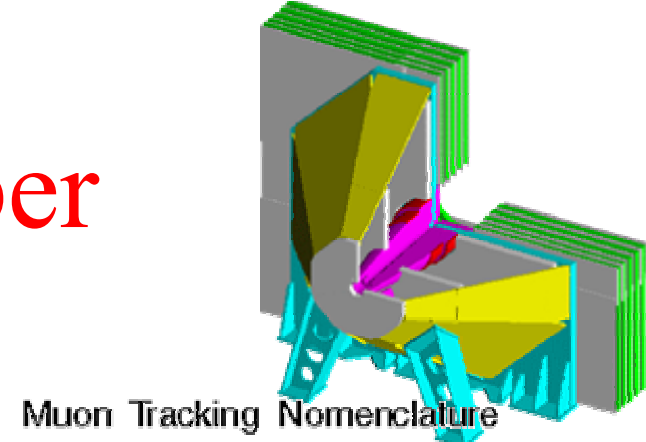
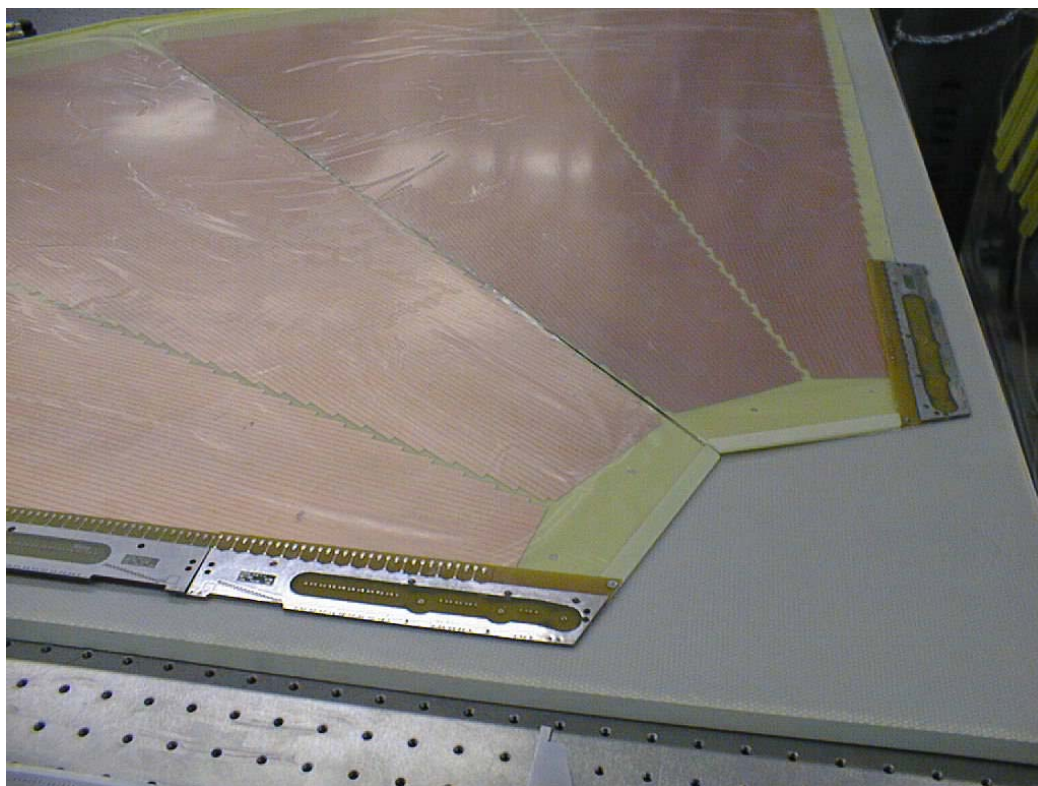
PHENIX Experiment

- Central Arms
 - Tracking,EMCal,PID
 - $|\eta| < 0.35$
- Muon Arms
 - Tracking+MuID
 - $1.2 < |\eta| < 2.4$
 - $\Delta\phi=2\pi$

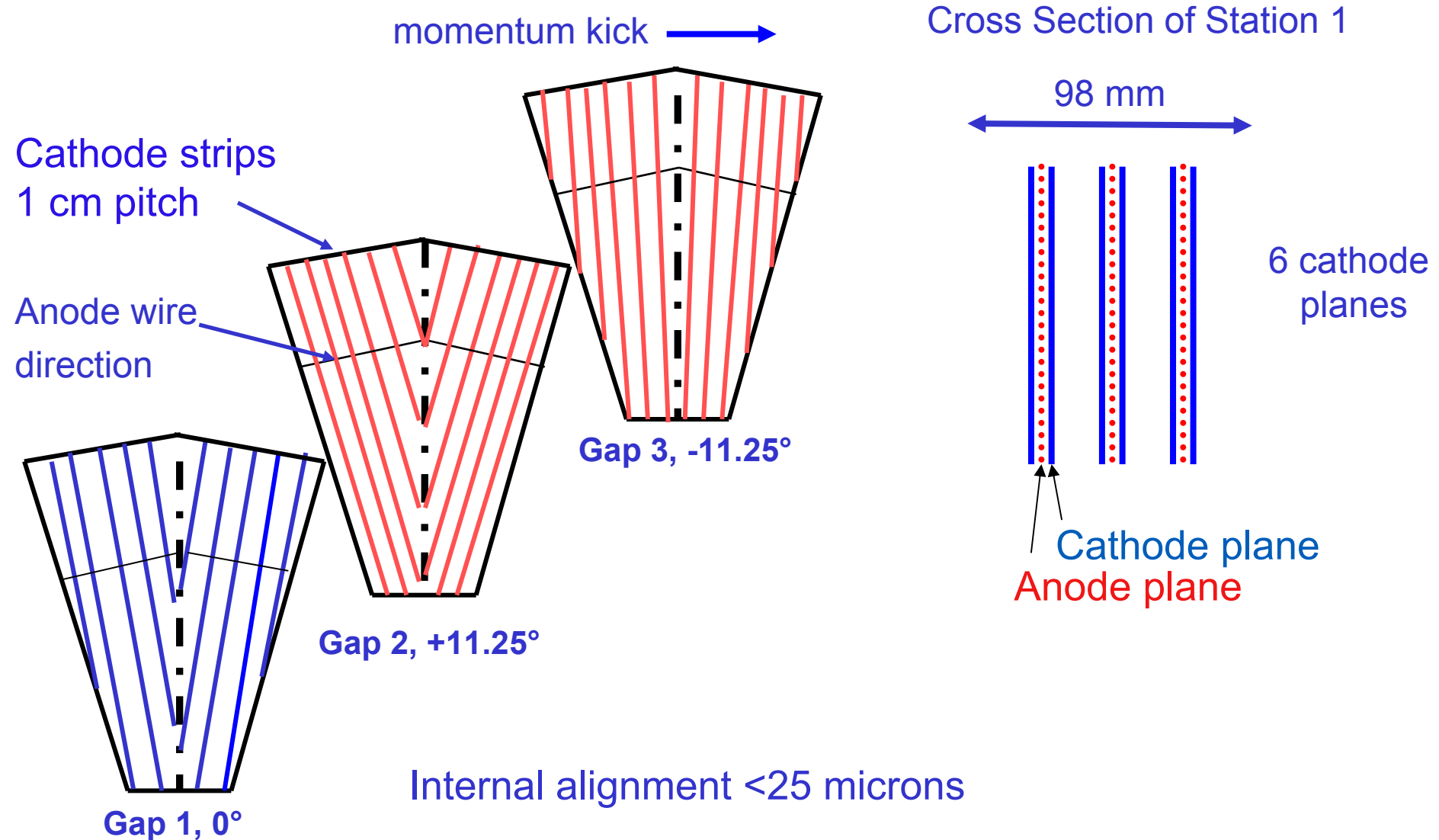


Muon Tracking Chamber

0.5 cm Cathode Strip Chamber



STRUCTURE OF A STATION



Muon FEE Design Specs

Good J/Psi mass
resolution

- Low Noise

- 100 μm resolution
1 cm cathode strip
readout
- input cap 10-150pF

- High Speed

- sample new data on
every beam crossing
- 4 samples per pulse
- hold 5 events
- 25kHz LVL-1 [40uS]

- Serial Control and Monitor

- FPGA, AMUADC, CPA
- Temp, Voltage, Current

- Performance

- 11 bits dynamic range[0-2047]
- typical charge 80fC (0.4-800fC)
- gain: 3.5mV/fC
- noise requirement 1% or 0.8fC
- pulse shape
 - rise time 0.7uS
 - decay time 10uS
- optical link to outside world
- reasonable power-up defaults;
- calibration control

Muon FEE

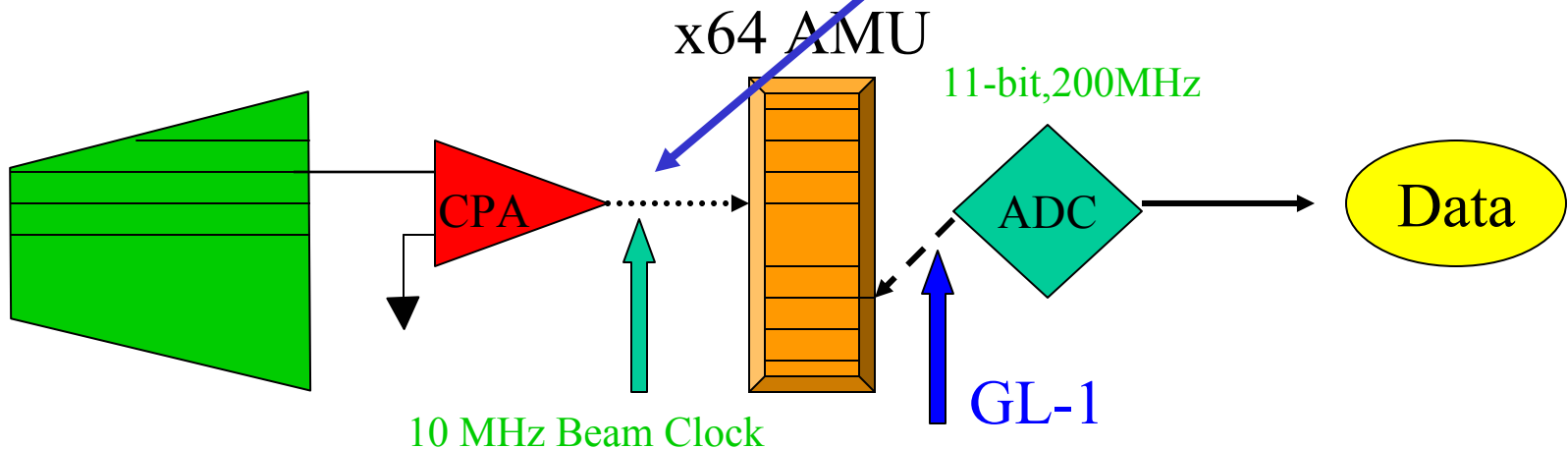
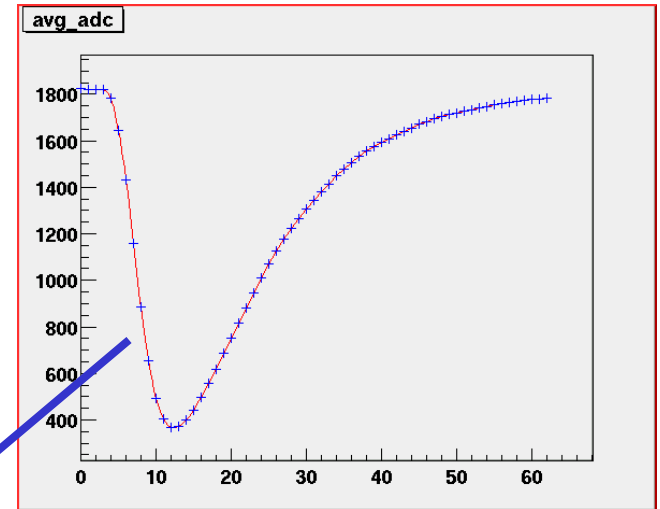
- Low noise high speed FEM

resolution : $100\mu m = x \cdot 1cm \Rightarrow x = 1\%$

noise : $Q' = 80 fC \cdot 1\% = 0.8 fC$

Thermal noise :

$$\frac{1}{2} \frac{Q_{thermal}^2}{C_{det}} = \frac{1}{2} kT \Rightarrow Q_{thermal} = 0.65 fC$$



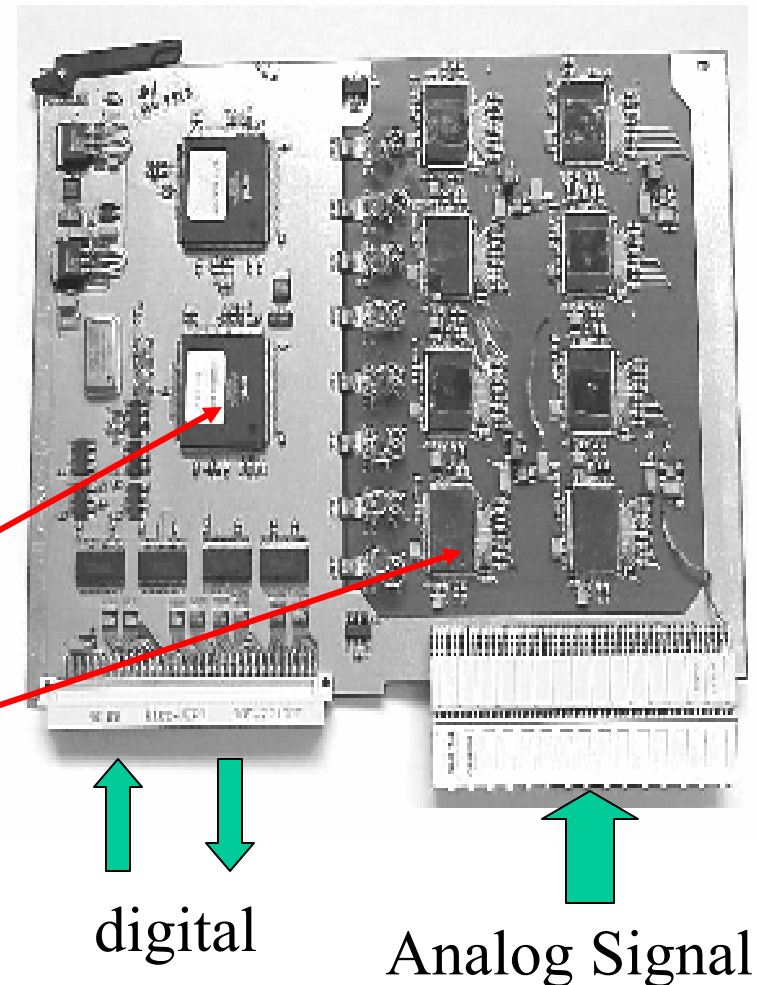
Cathodes Read-Out Card (CROC)

- Design Requirements

- 64 Channel Readout per CROC
- Less than 3125 electrons (RMS) noise for 10-150 pF of detector capacitance (including 24" cable) •
- Less than 1% crosstalk between any channels on the board
- gain: 3.5mV/fC
- Digital/Analog isolation

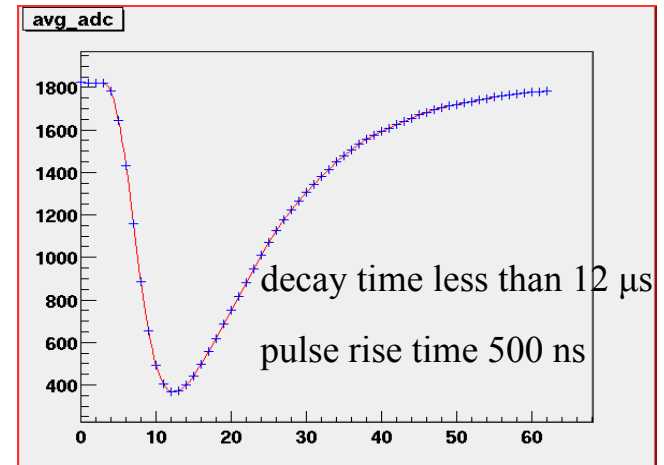
- Main Components

- AMU-ADC
- CPA

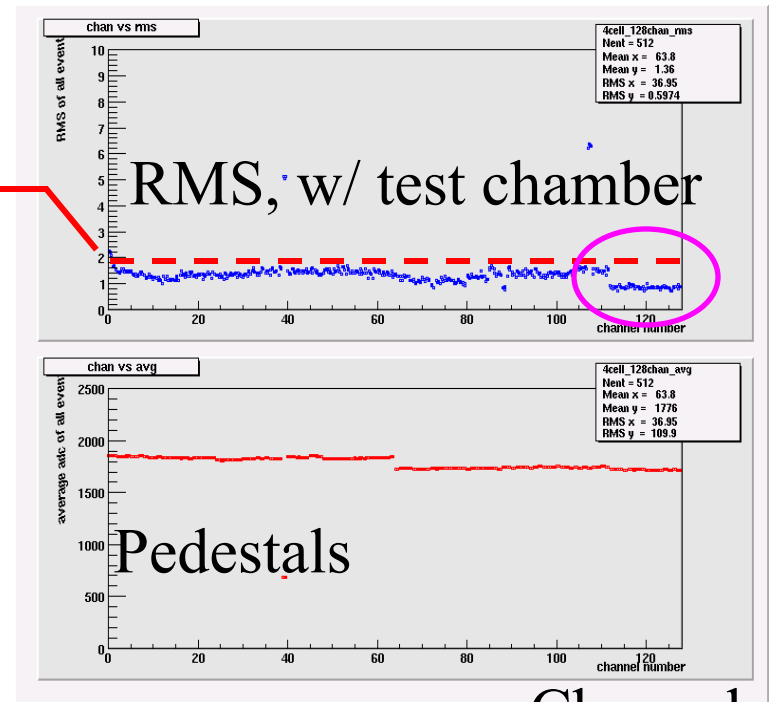


Muon FEE - CROC

- CPA(Charge Pre-Amp)
 - low noise (<3000 e's)
 - 8-channel preamp/shaper
 - 34-bit serial control
 - pedestals
 - pulse shape
- AMU-ADC
 - 32 channels
 - 64-cell AMU
 - serial control
 - V_ref, I_ref
 - 9-12 bits ADC conversion
 - 200MHz clock



Noise Spec



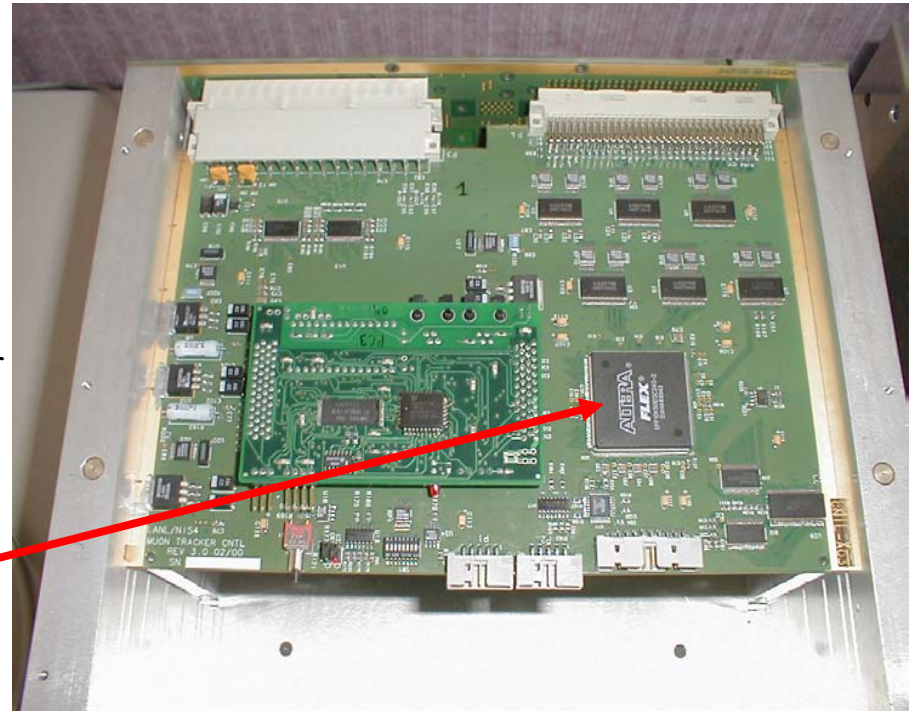
Controller Card (CNTL)

- Design Requirements

- Control AMU/ADC data collection, conversion and read-out
- Provide connection to 2 CROC boards
- Provide connection to the outside world
- Support the T&FC and DCM interface
- Provide data relay from remote controller board to DCM
- Support ARCnet connectivity to serial configuration bus

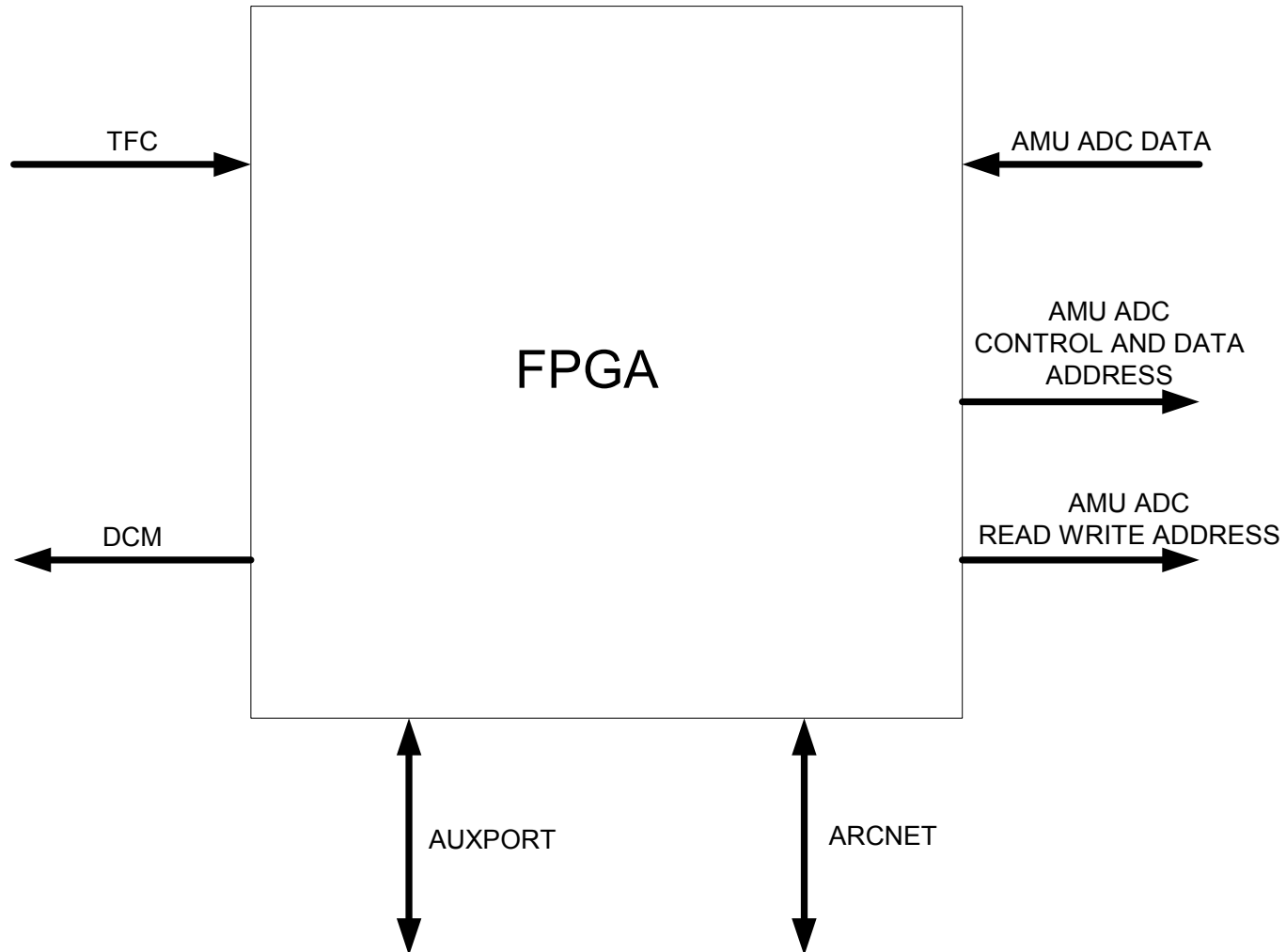
- FPGA - the brain

- developed by Jack
- work in progress



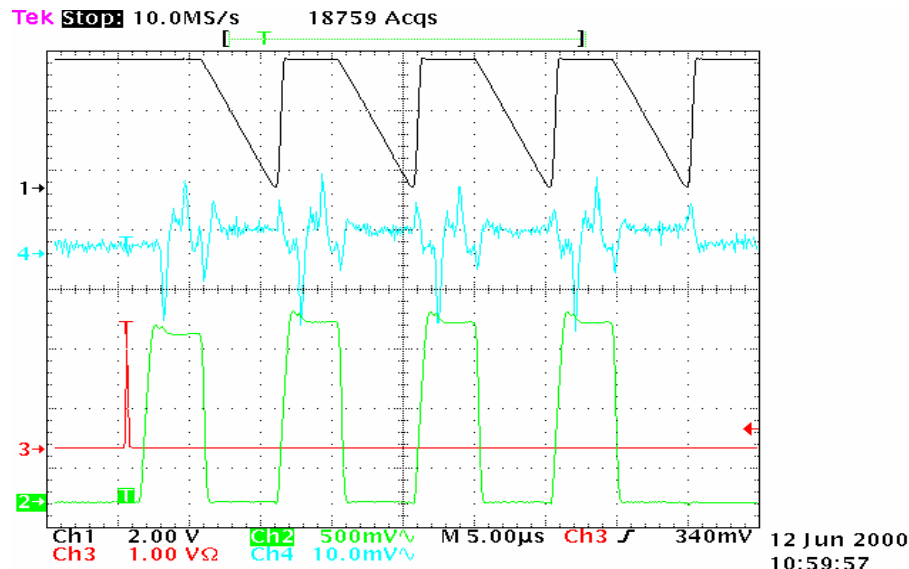
CNTL Card

MUON TRACKER CNTL FPGA

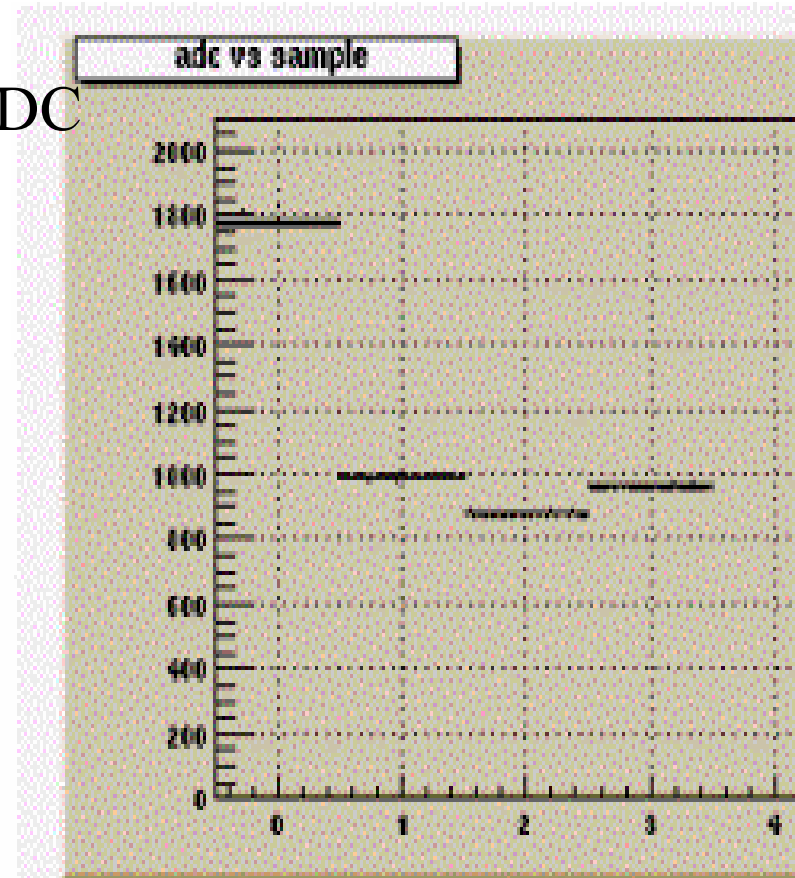


Muon FEE

- FPGA - current code
 - store every beam crossing
 - 4-sample per pulse
 - readout time 53uS
 - hold 4 events



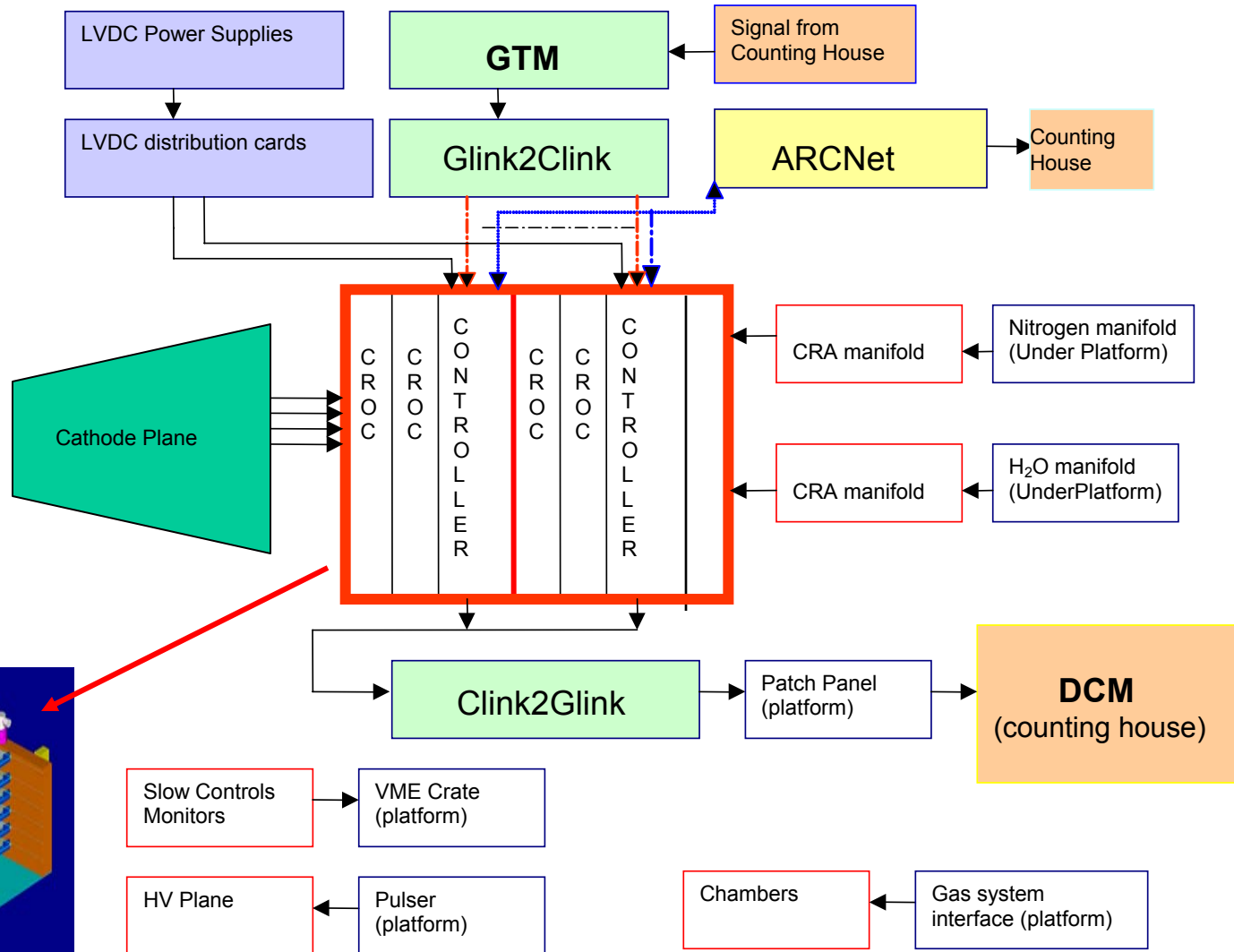
ADC



Time

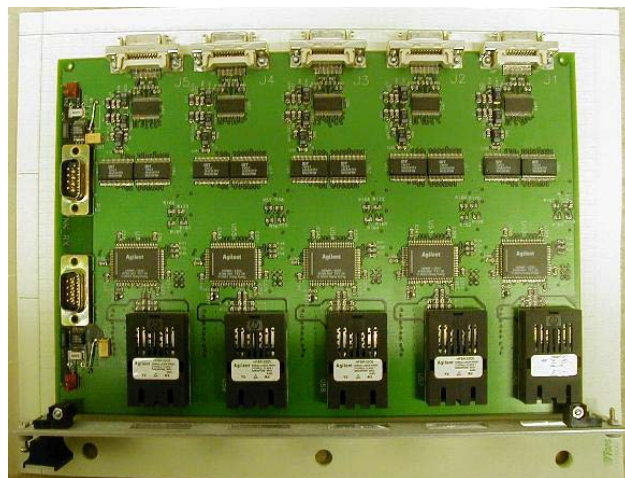


Muon Tracking FEE Overview

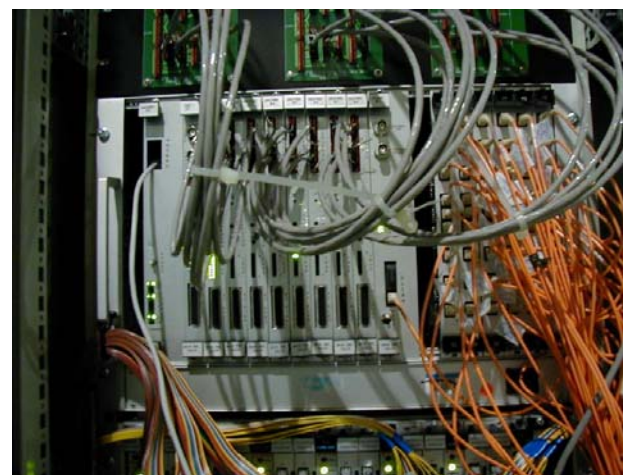
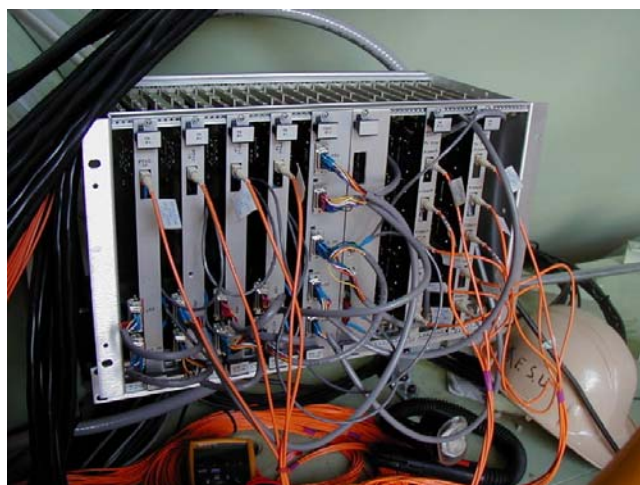
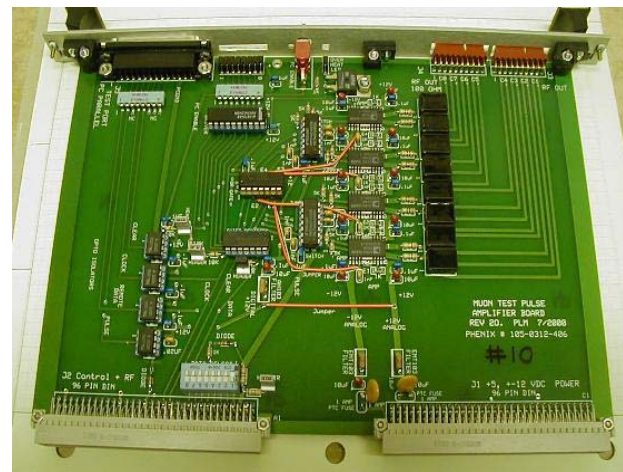


Supporting Muon Tracking Electronics

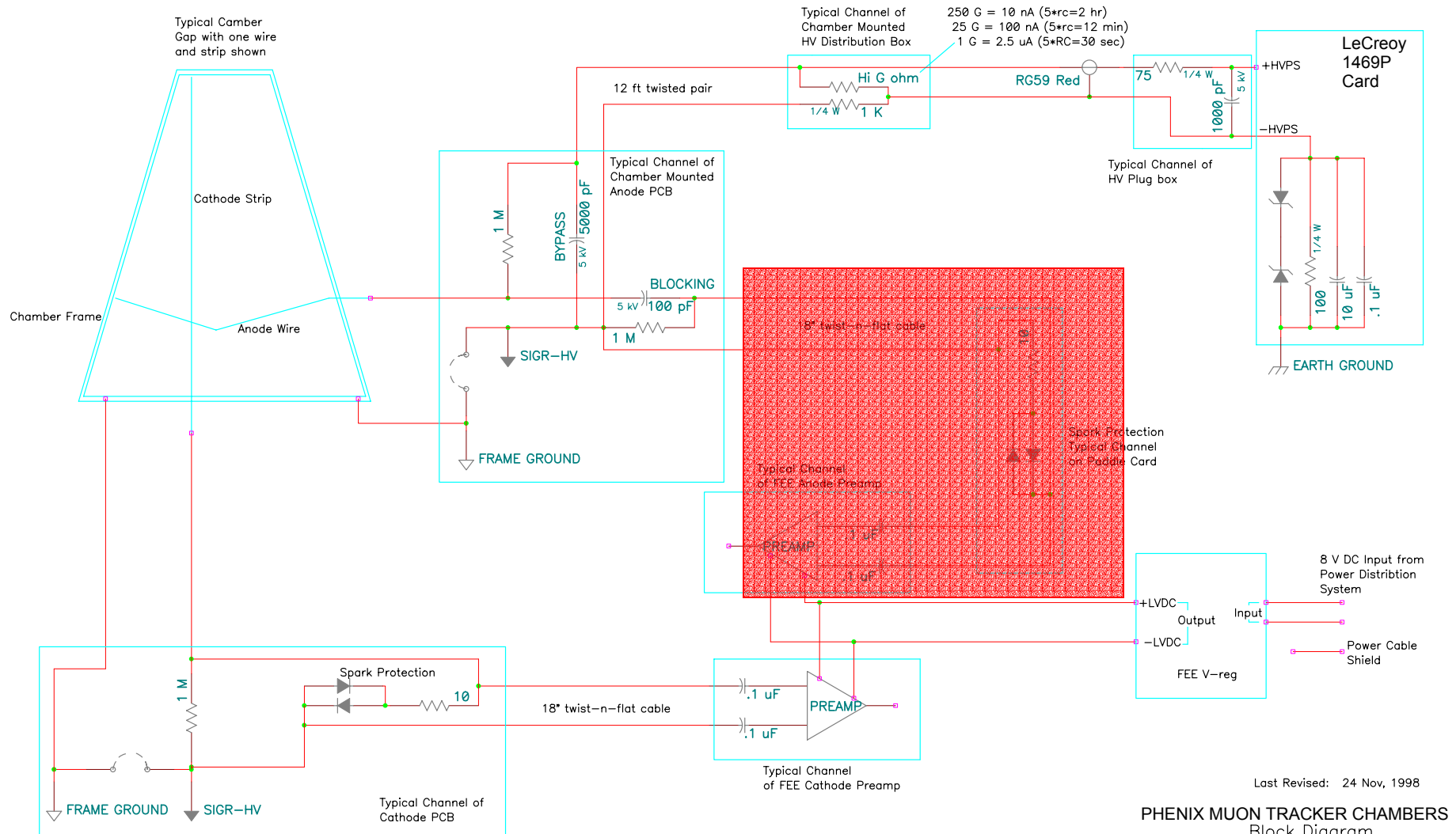
G/Clink cards



Calibration



System Diagram



Last Revised: 24 Nov, 1998

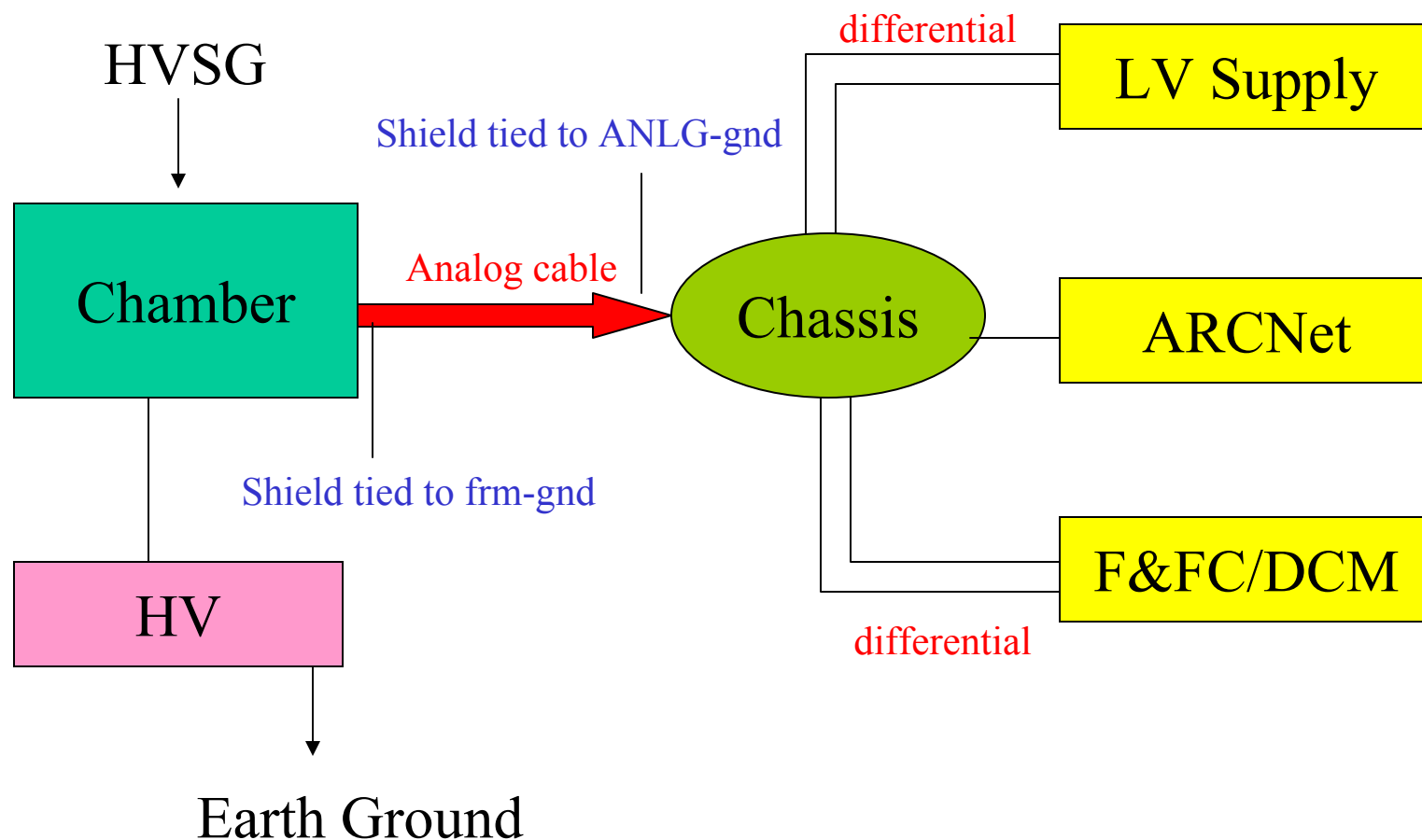
PHENIX MUON TRACKER CHAMBERS
Block Diagram

-Electrical-

28 July, 1998
MuTr Block

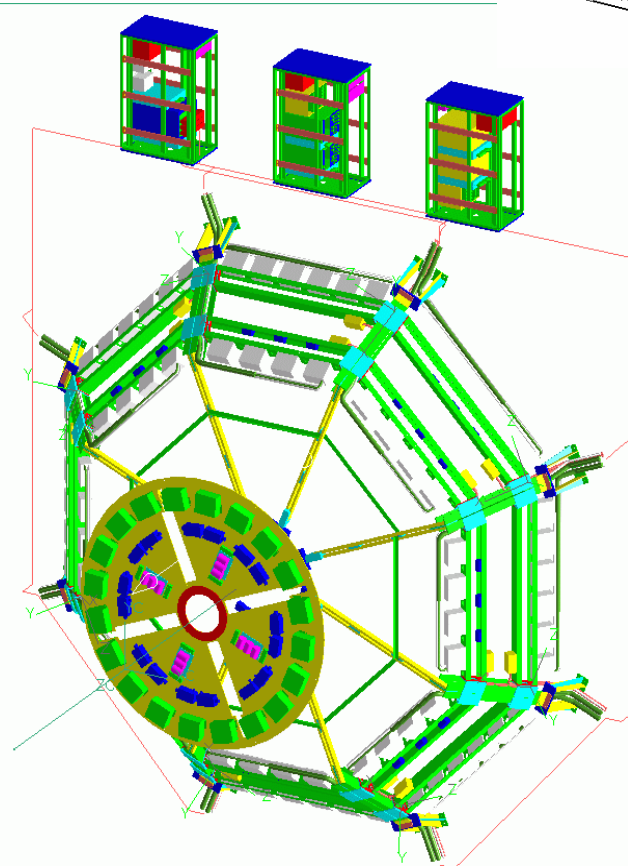
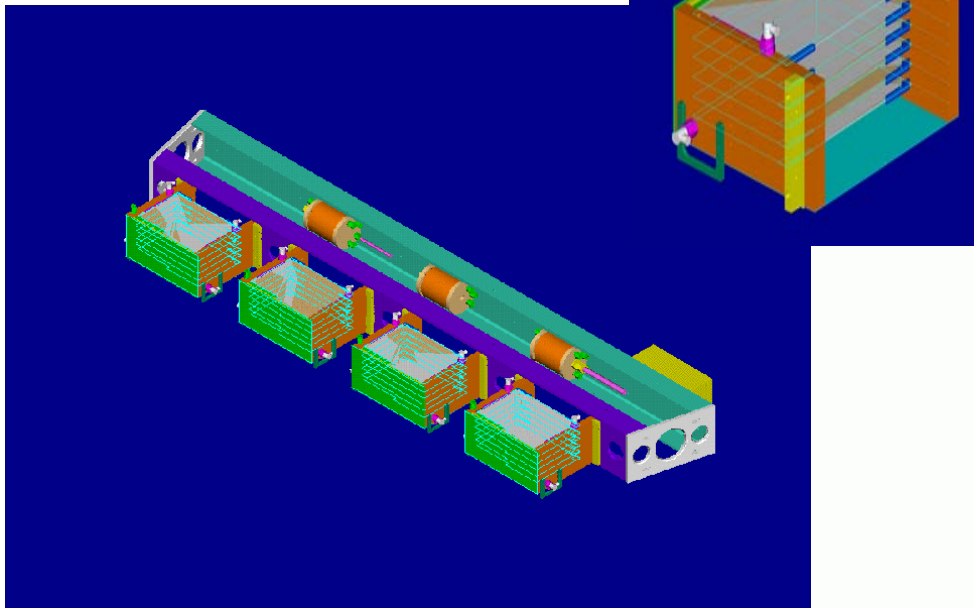
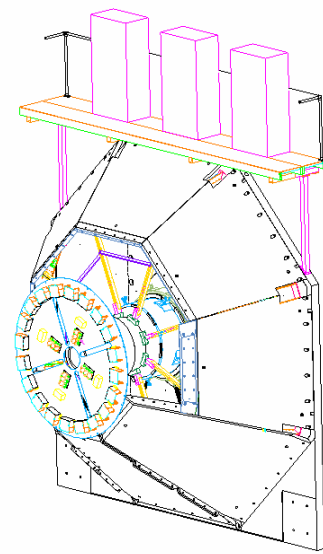
G Hart

Grounding Configuration

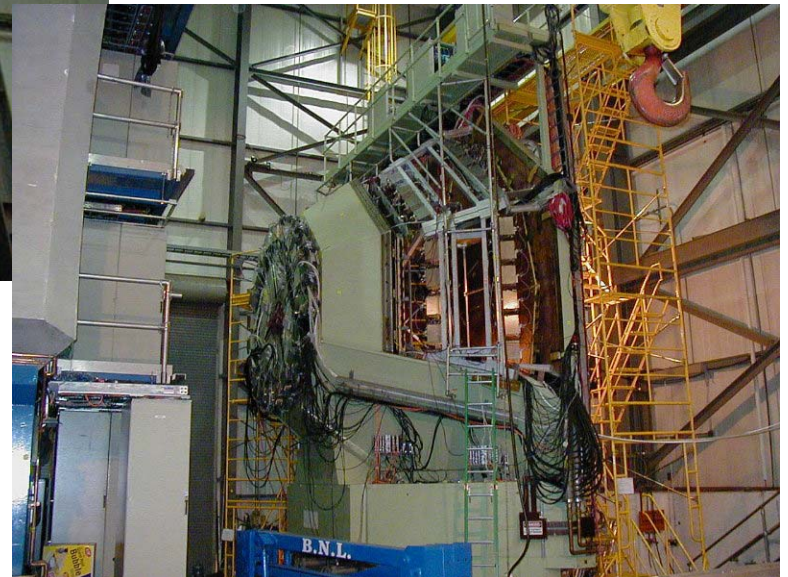
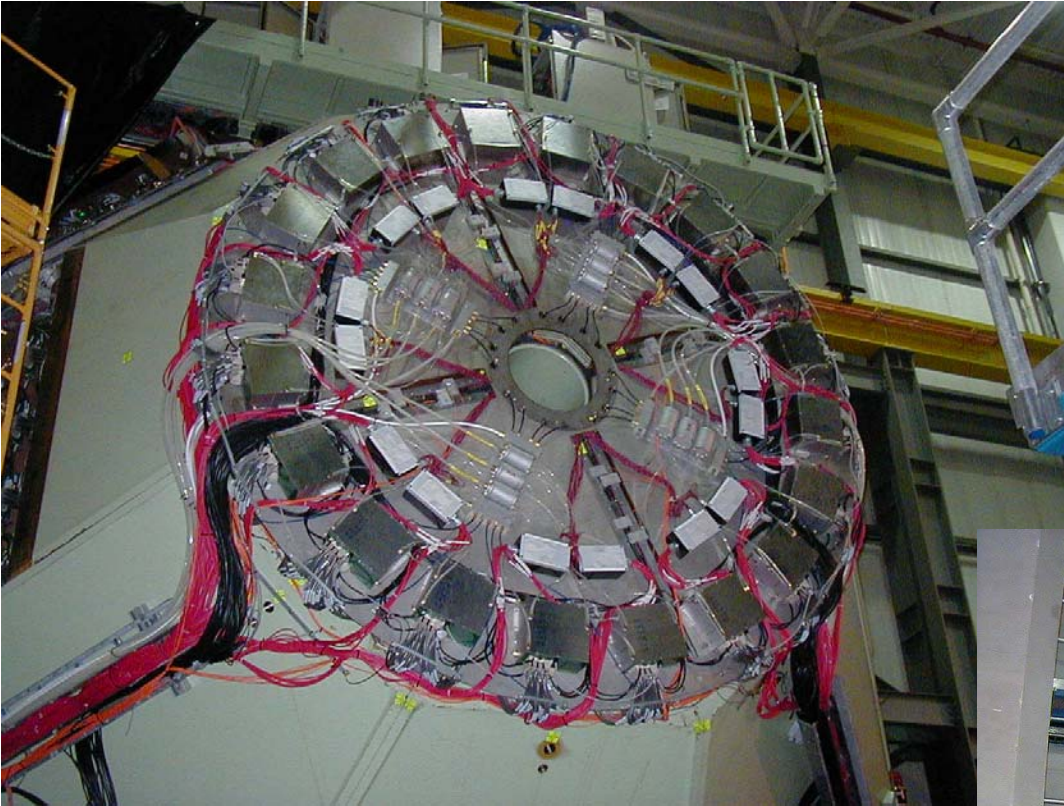


FEE Overview

- Inside Magnet/no access
- Limited Space
- Power constrain
- Many Channels
 - 168+192 FEMs
 - over 40,000 channels

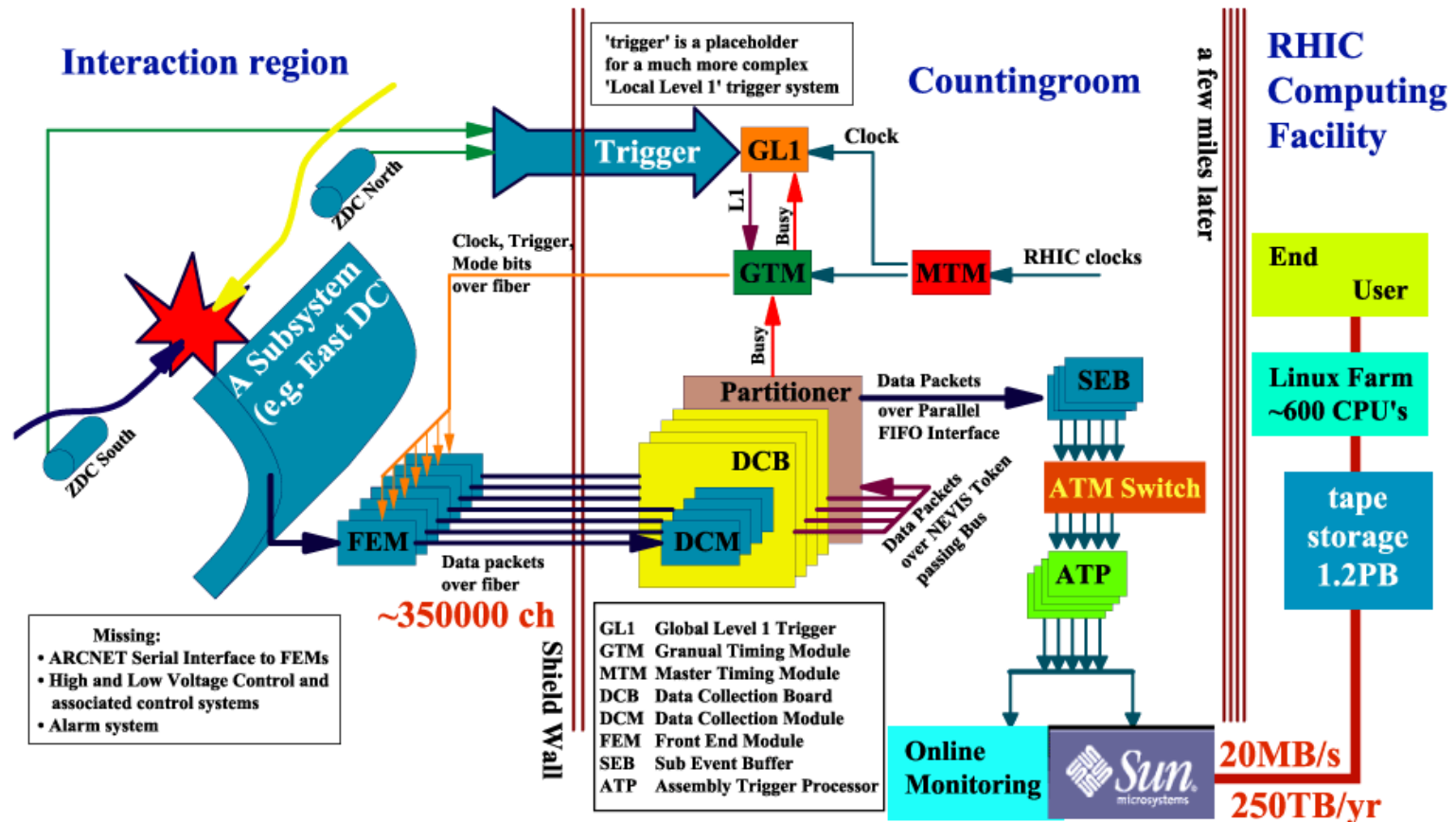


PHENIX South Muon Tracker



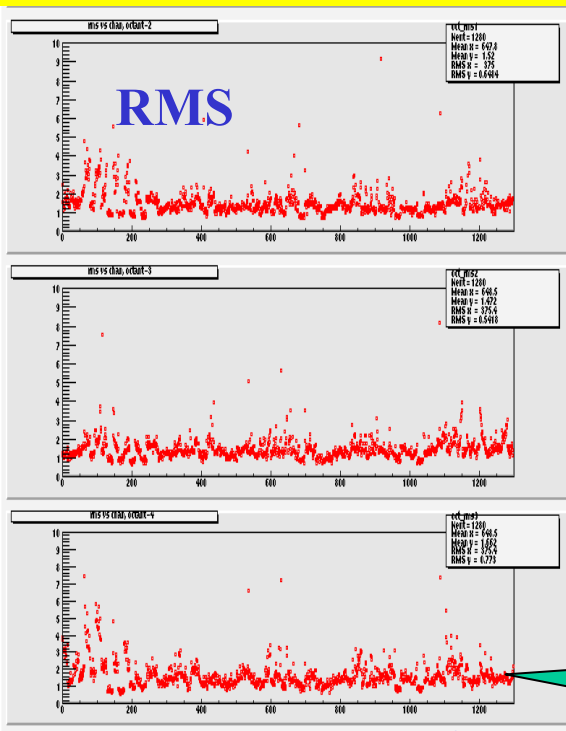
Interface to PHENIX DAQ

- Data readout and DAQ system

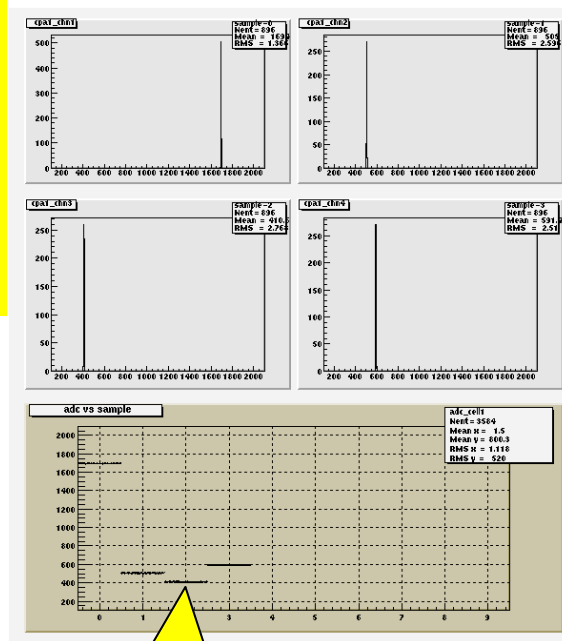


Detector Commissioning

- Electronics
- HV
- Noise Reduction
- Timing in Detector

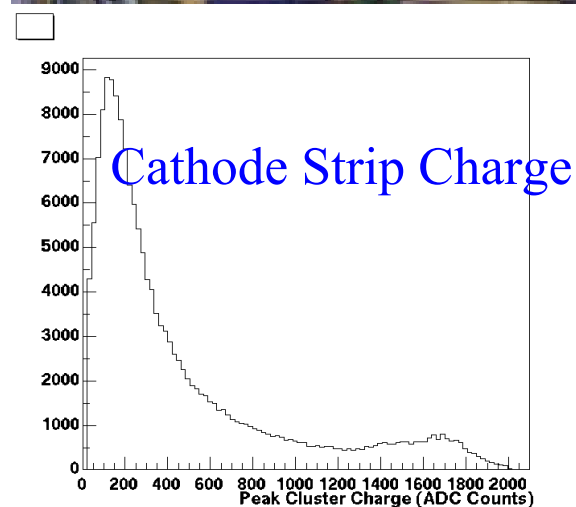


Channels

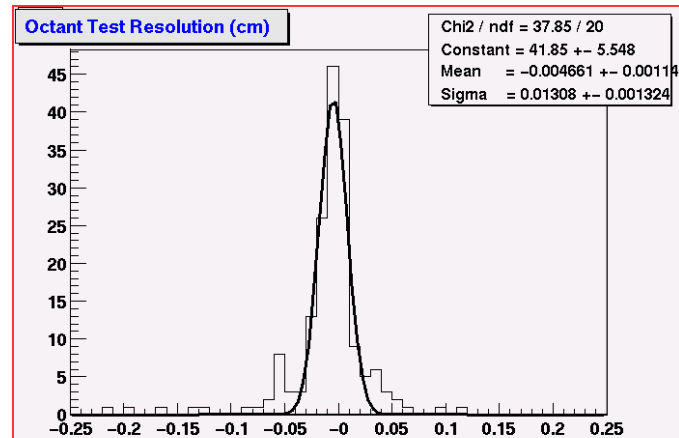


Good Timing

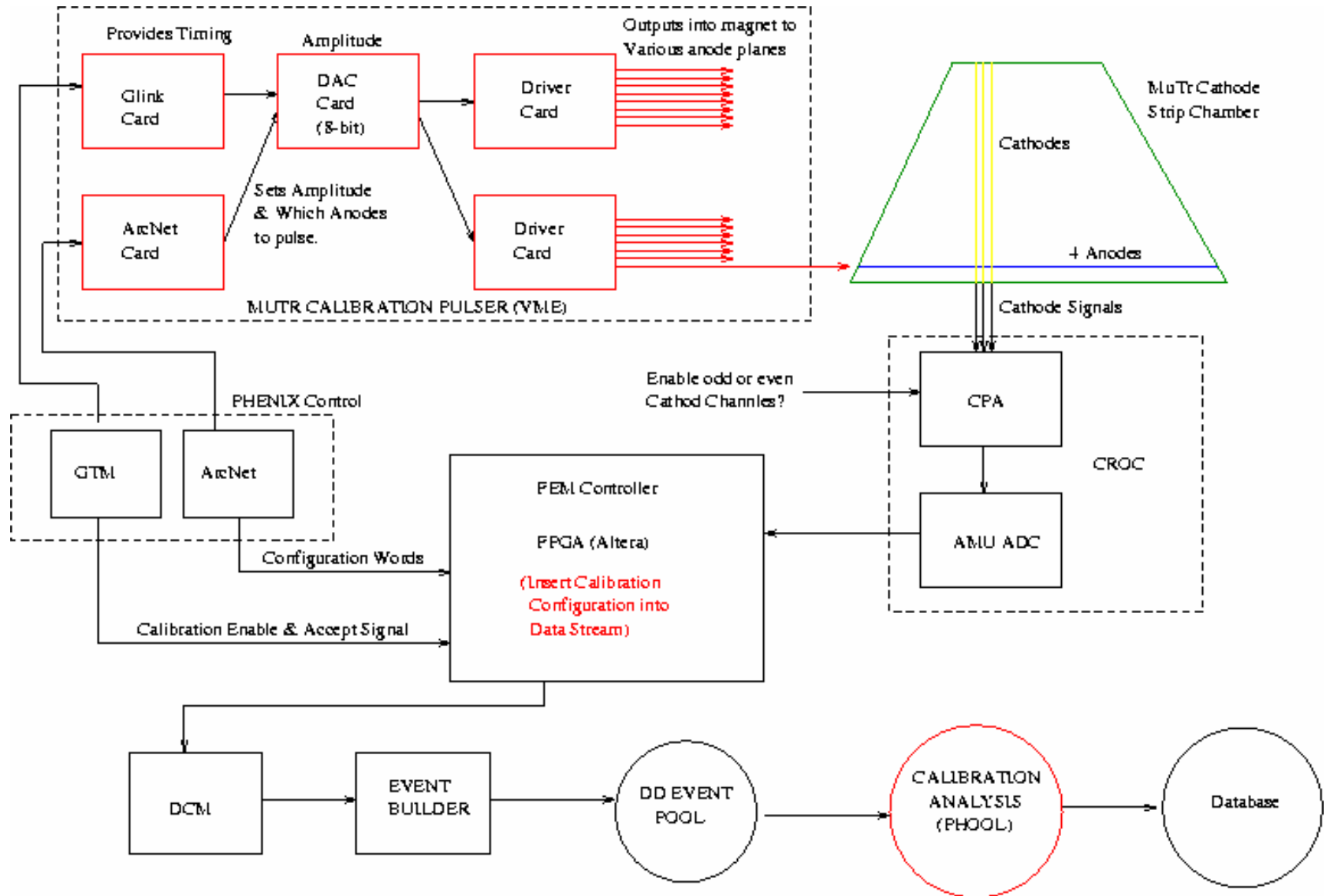
Low noise
rms ~ 2 ADCs



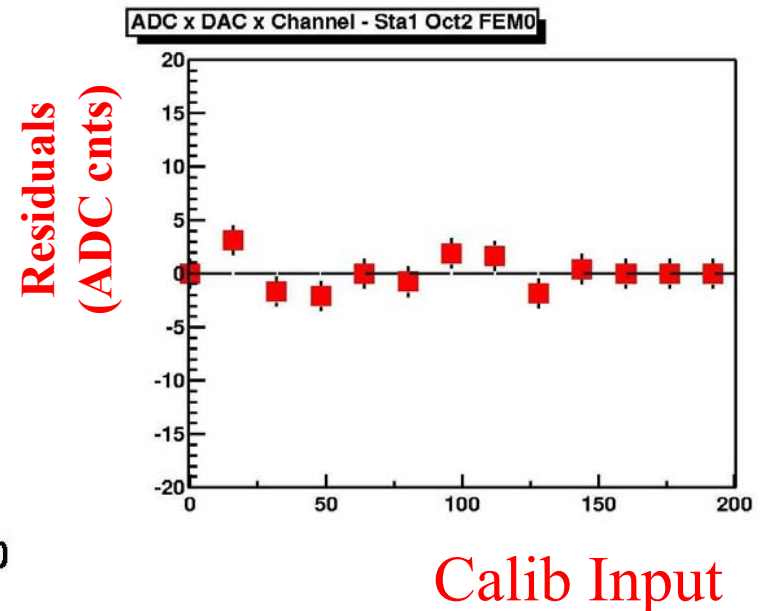
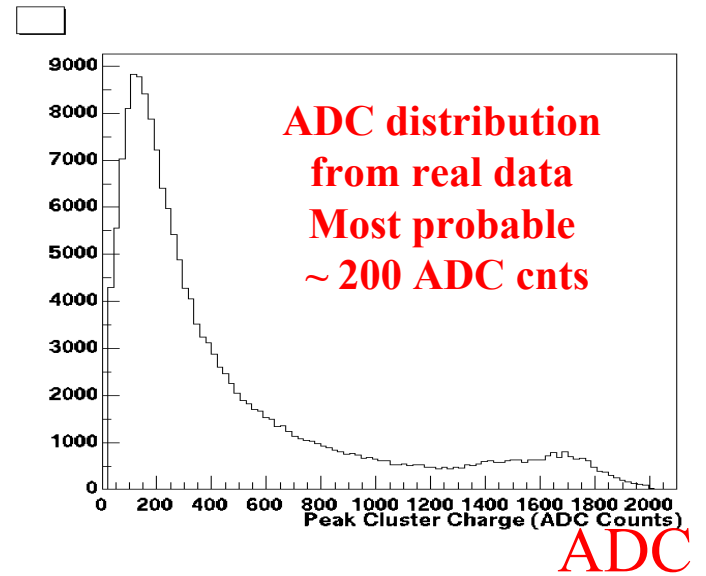
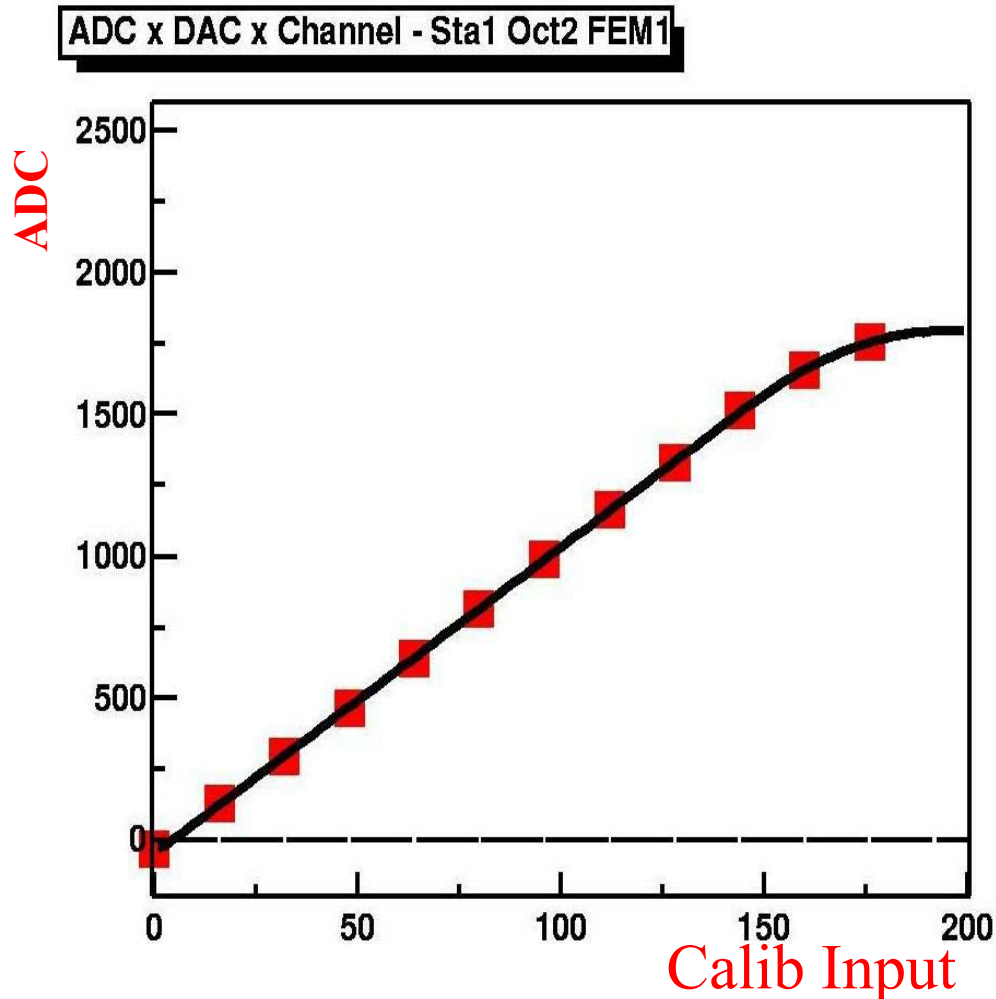
chamber resolution ~100um



Muon Tracker Calibration System



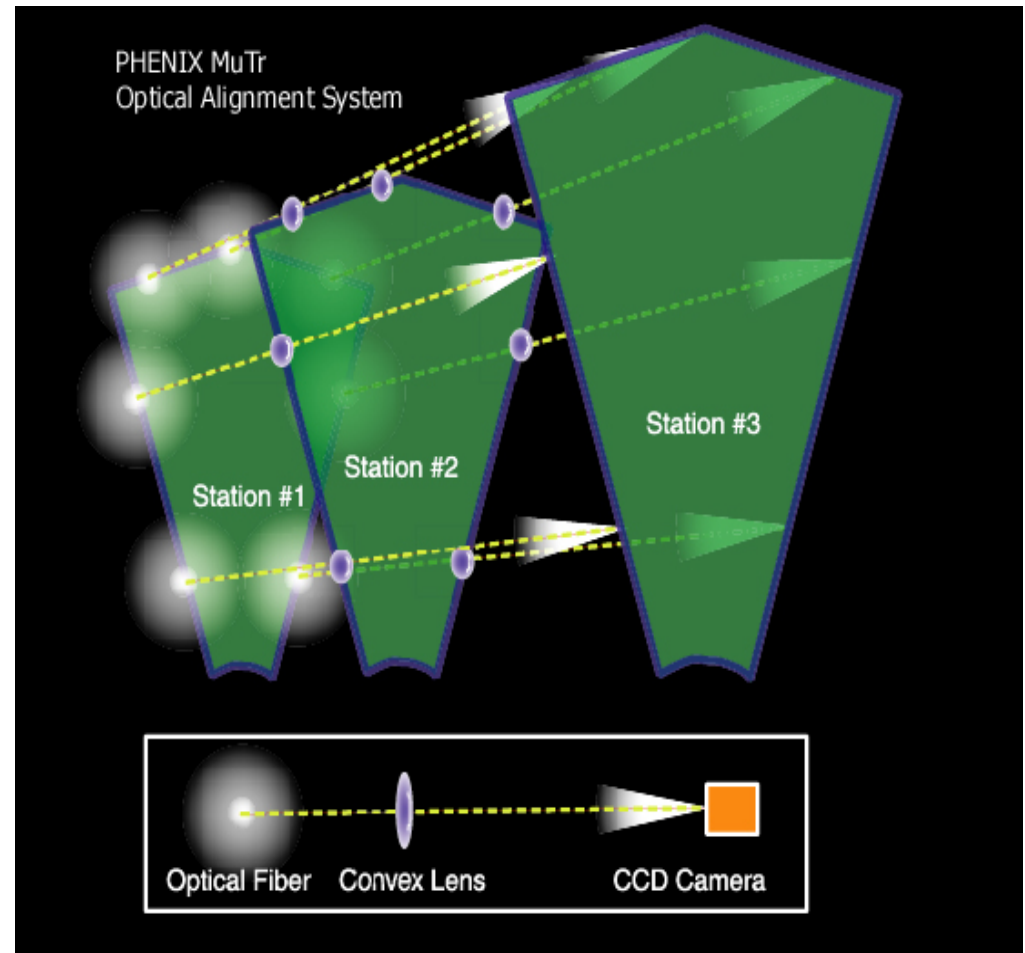
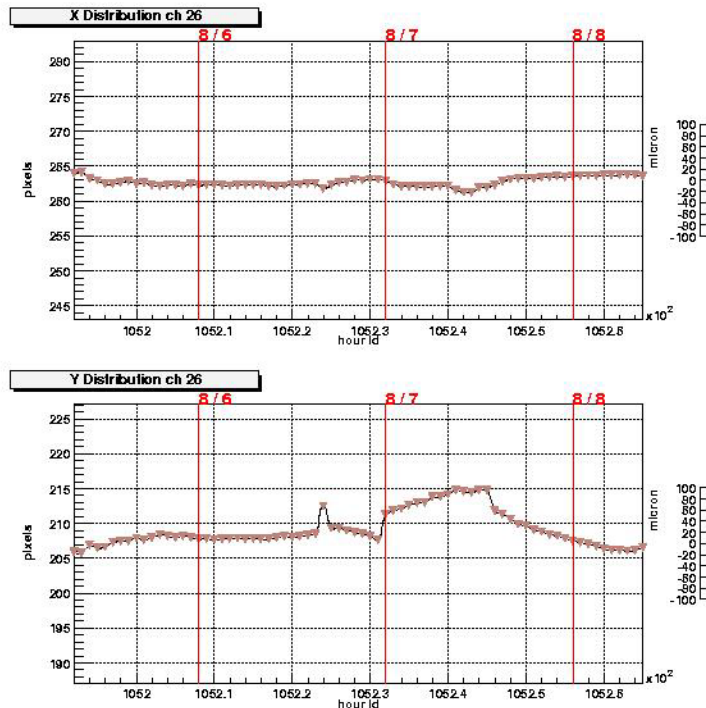
Calibration



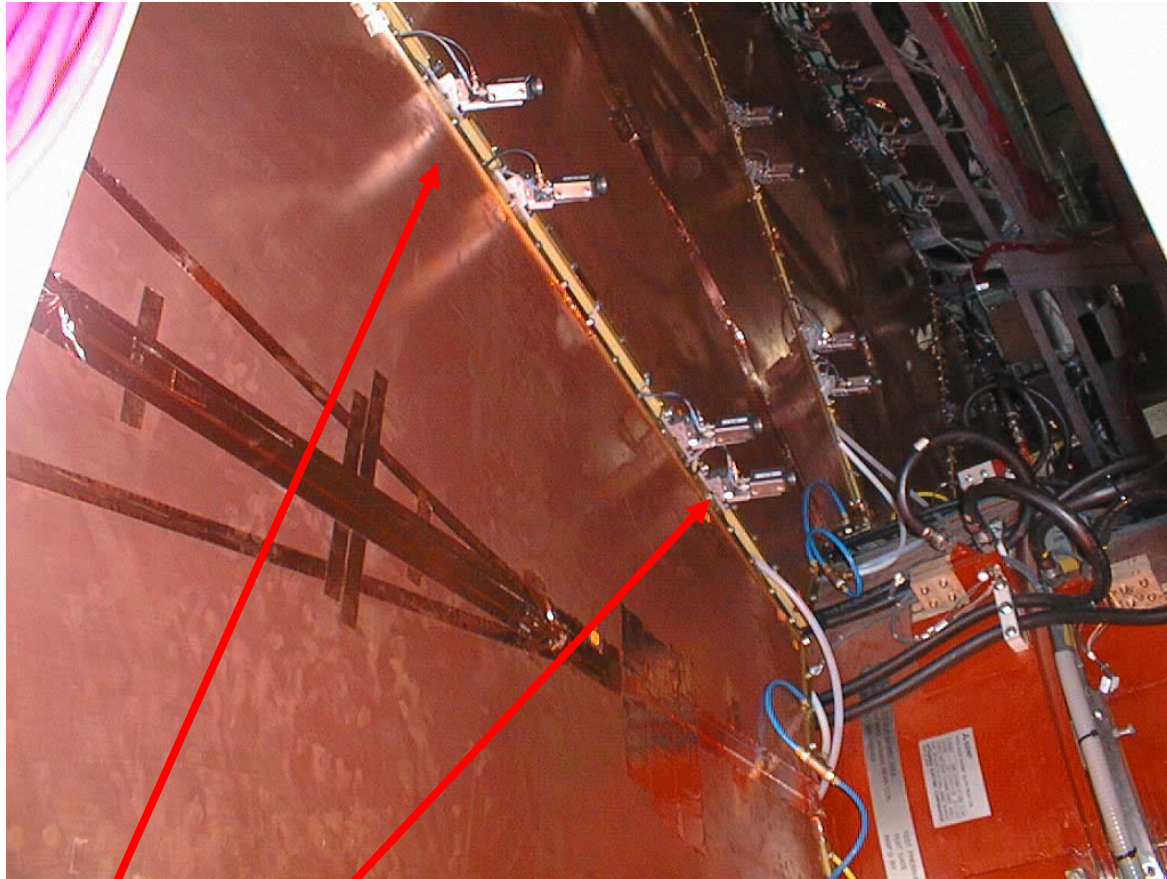
Chamber Alignment Monitoring

A good tracking resolution:

- low electronics noise
- stable gain
- geometry and alignment



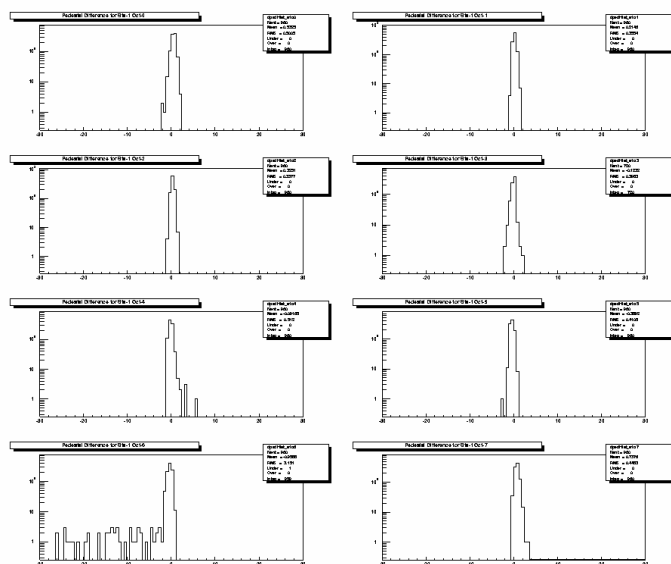
Optical Alignment System



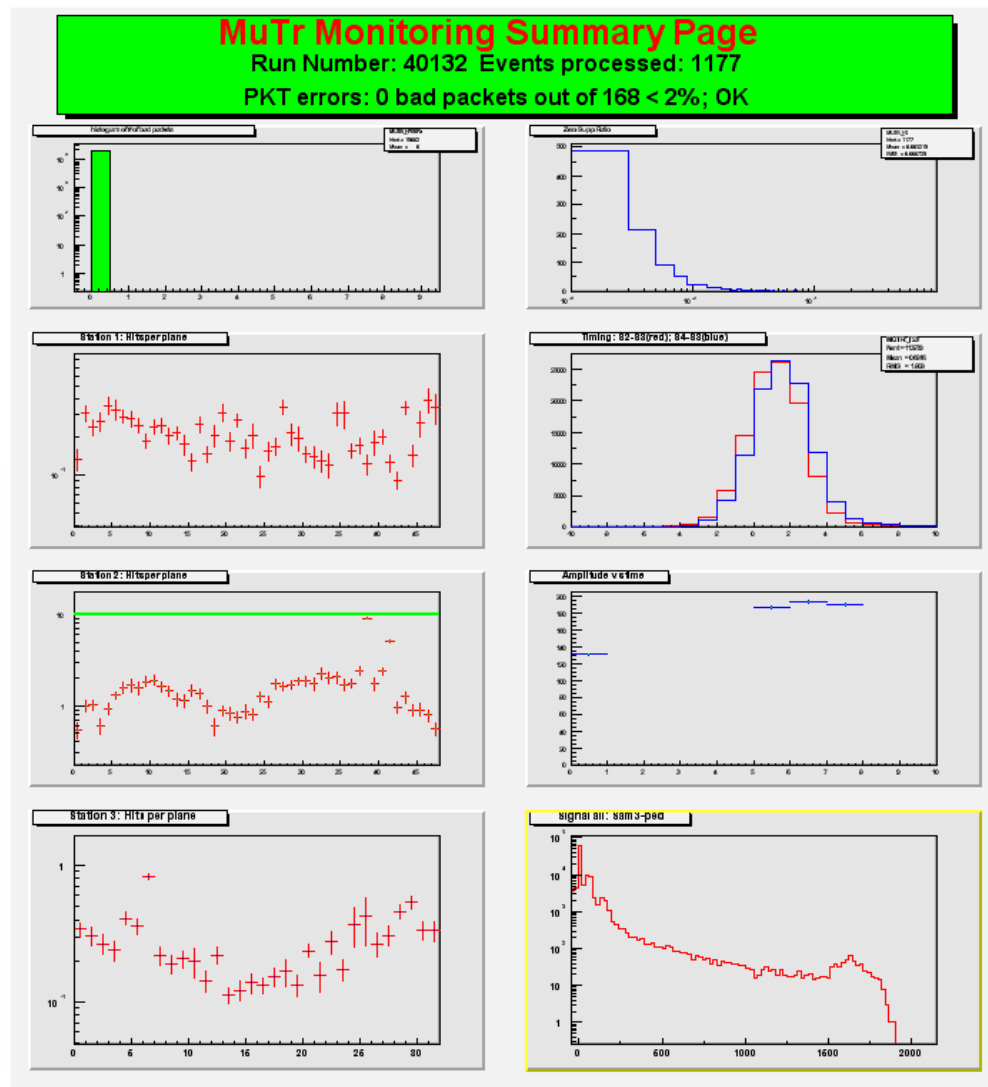
Cameras on station-3 chambers

Data QA: calib. & online monitor

- 4 Samples' relative timing
 - (1,6,7,8) beam-crossings
- DAQ Zero-Suppression (<5%)
 - (peak - pedestal)>3*rms
- Stable Pedestals and Gains
 - daily calibration



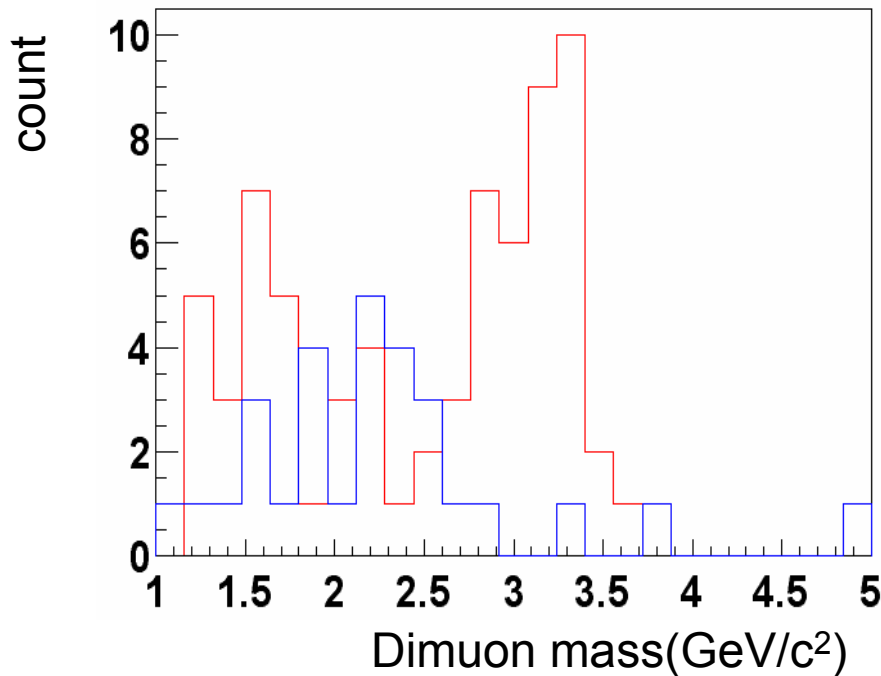
Pedestals from calibration data



Dimuon Mass

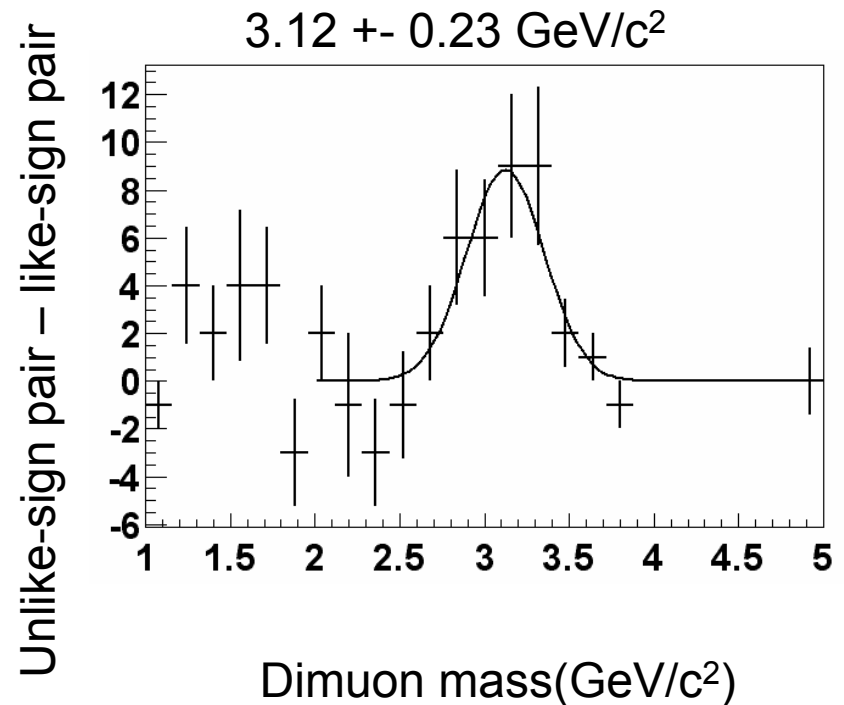
Red: unlike-sign pair

Blue: like-sign pair



$$J/\psi(c\bar{c}) \rightarrow \mu^+ \mu^-$$

$$M_{J/\psi} = 3.1 \text{ GeV}$$



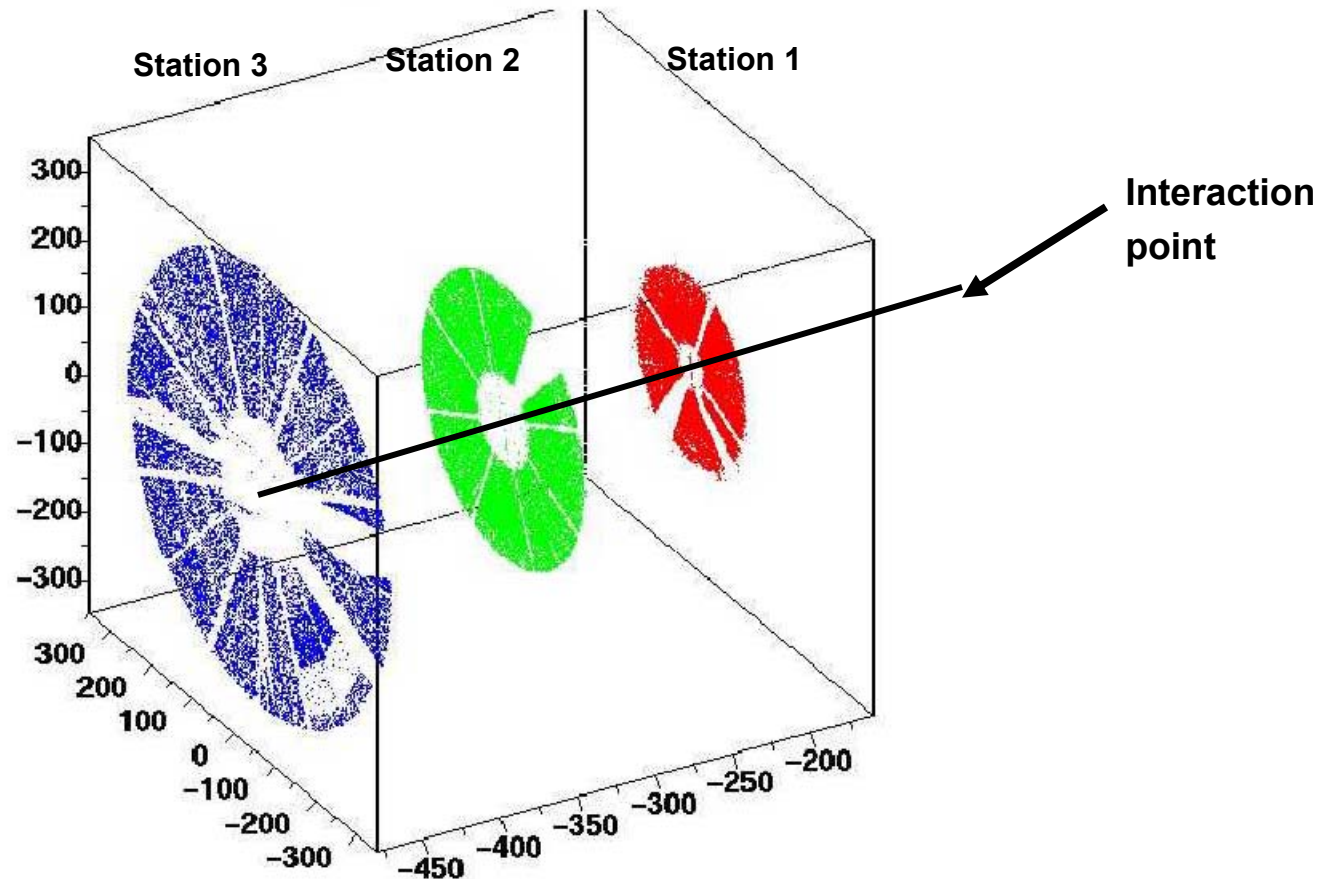
Significant enhancement of unlike-sign pair in the J/ψ mass region

- Peak ($3123 \pm 56 \text{ MeV}/c^2$) is consistent with J/ψ mass
- Mass width ($230 \pm 40 \text{ MeV}/c^2$) is consistent with expectation -> further improvement is expected

Current Status and Issues

- Worked as expected in Run-2
 - no major problems
 - luminosity was low
- G/Clink loss and readout problem
 - very sensitive to external disturbance --> replaced all bad cables
 - “dead” FEMs, ~5% -> loss acceptance
 - can't re-lock on the fly ->DAQ hung
- For higher luminosity (Run-4, 5, ...)
 - conversion time 53 uS is too long [40]
 - need to hold 5 events
 - new FPGA work in progress

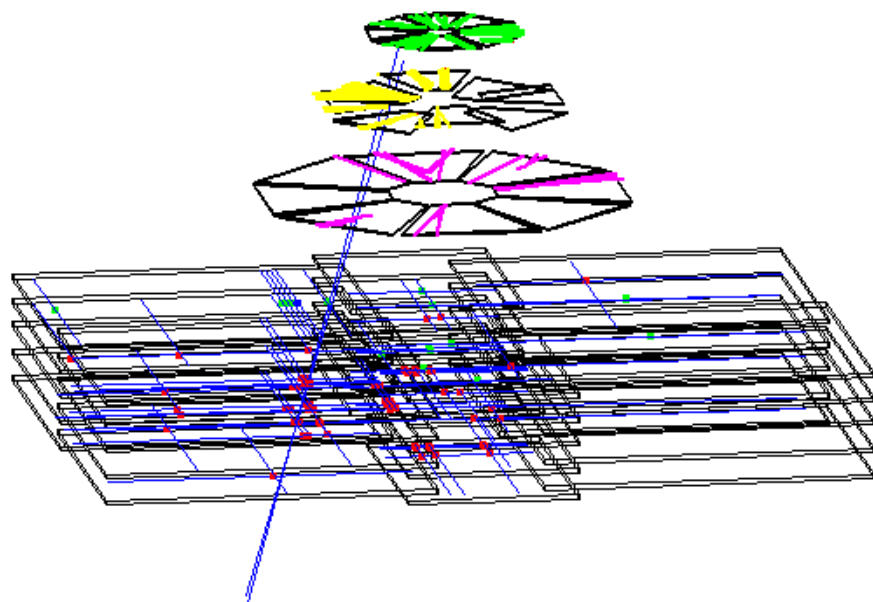
ACTIVE MUON TRACKER CHANNELS



Visualization of active regions of three tracking stations. Dead regions are due to problems with HV and front end modules during 2001-2 run. Majority of problems corrected for next run.

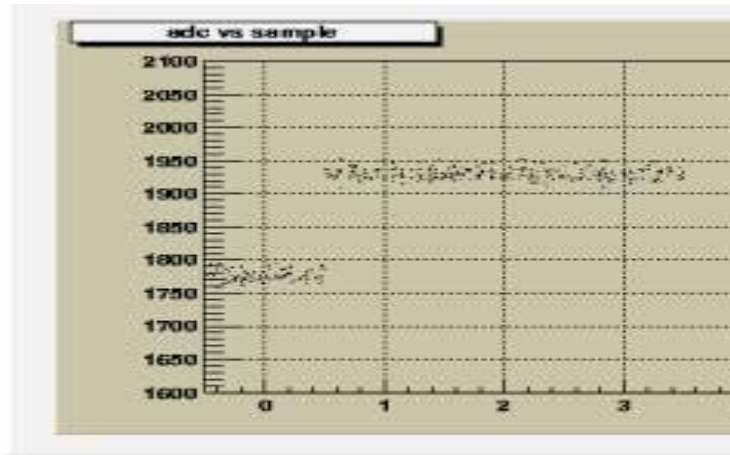
Summary and Outlook

First collision events were
observed on 07/18/2001

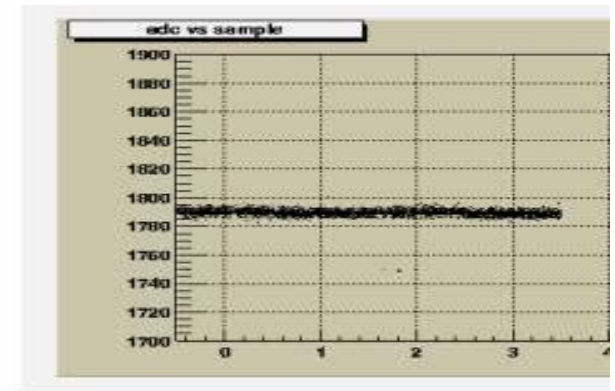
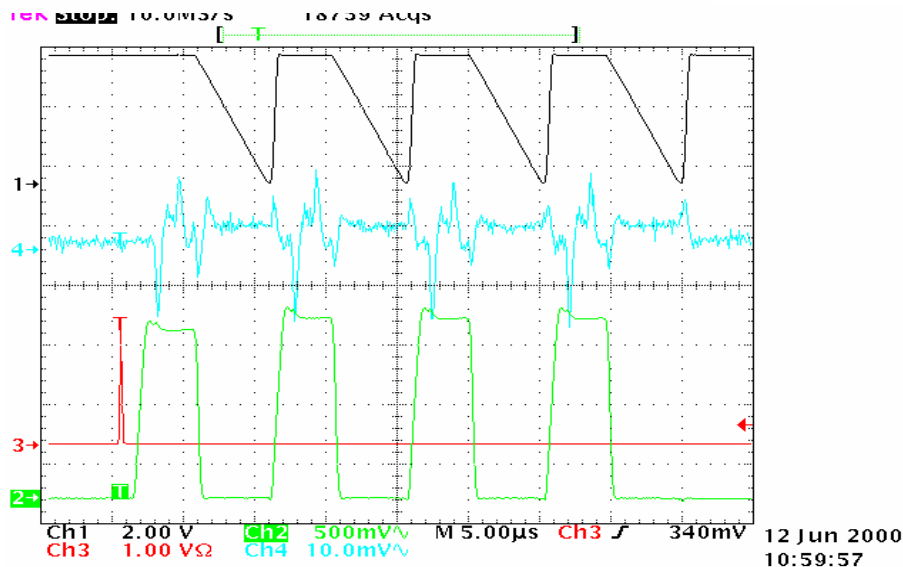


- Successfully installed and commissioned muon detector in the PHENIX
- **More work to improve FPGA code to handle:**
 - 5 events buffer(4)
 - 40uS conversion (53)

Conversion Time and Baseline Shift - AMUADC



- Problem is eliminated by adding 4 μ S delay between conversion and data transfer (add 12 μ S).
- Possible remedial actions
 - tune delay to minimize
 - use only three samples
 - relax requirement for five events



Disabled HV & FEMs

- HV

- Station-1,2,3

- 1825V:1850:1850

- 72/304=23.7% disabled

- FEMs (total 168)

- Sta-1: 4/40

- Sta-2: 2/64

- Sta-3: 2/64

were disabled

(loss ~15% acceptance)

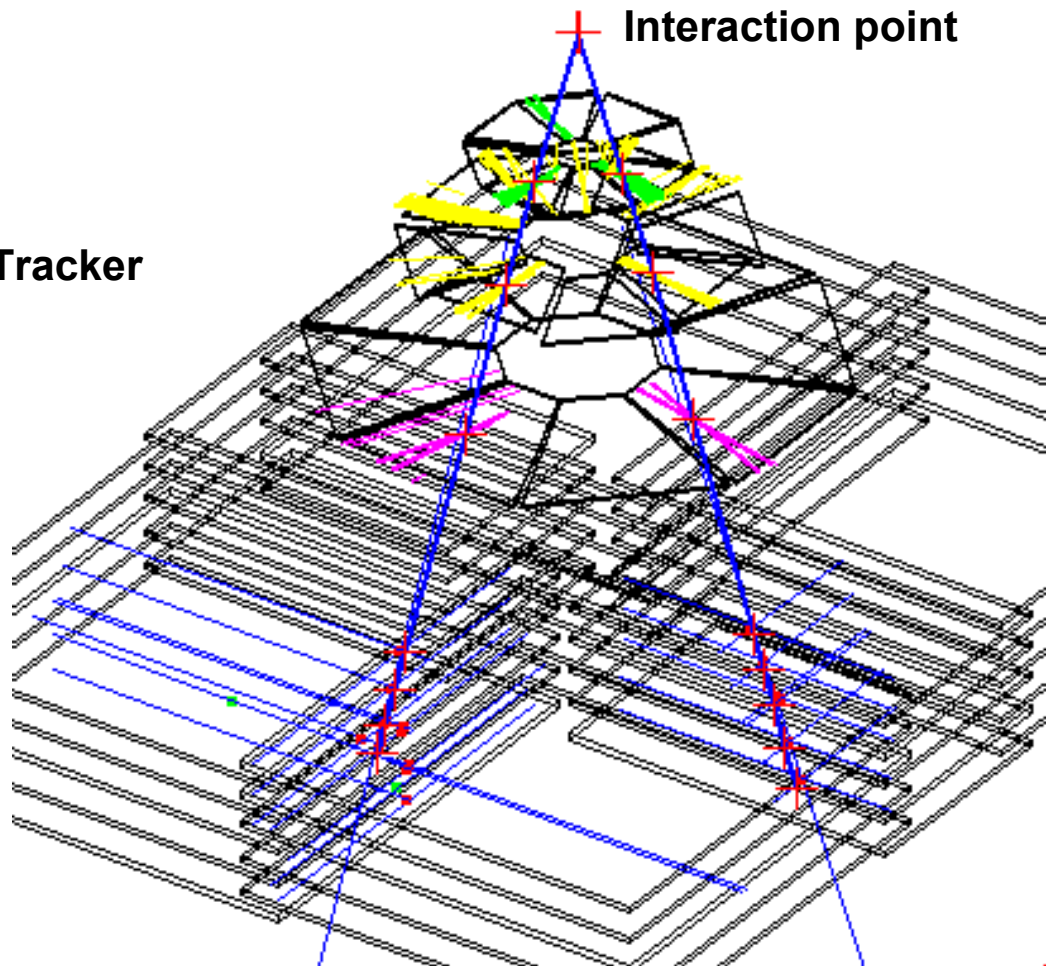
SOUTH MUON TRACKER HV SUMMARY

S111	S112	S113	S121	S122	S123	S131	S132	S133	S141	S142	S143
1824	1825	1824	1825	1825	1825	1825	1825	1825	1825	1824	1825
0.020	0.110	-0.010	0.000	-0.010	0.100	-0.010	0.120	0.020	0.000	0.040	0.020
0.010	0.130	0.000	0.000	-0.010	0.050	0.010	0.070	0.040	0.030	0.000	0.000
-0.010	0.210	0.030	0.050	0.090	-0.050	0.000	0.150	0.000	-0.140	0.170	-0.040
0.150	0.120	-0.040	0.050	0.000	0.190	0.050	0.080	0.010	0.020	0.000	0.050
0.010	0.140	0.000	0.020	0.010	0.080	0.040	0.080	0.020	-0.050	-0.010	-0.080
0.000	0.150	0.050	-0.050	-0.060	-0.030	-0.010	0.040	0.060	-0.110	0.000	-0.050
-0.010	0.030	-0.100	0.120	0.070	0.140	0.030	0.180	0.000	0.000	0.020	0.100
0.080	-0.020	0.000	0.090	-0.030	0.130	0.000	0.110	0.100	0.000	0.010	0.000
S151	S152	S153	S161	S162	S163	S171	S172	S173	S181	S182	S183
1826	1826	1826	1829	1824	1824	1825	1825	1826	1826	1824	1825
-0.010	0.000	0.000	0.030	0.000	0.010	0.000	-0.030	0.000	0.020	0.000	0.000
0.000	-0.020	0.000	0.030	0.000	0.030	0.000	0.000	0.000	0.000	0.000	0.000
-0.070	0.060	0.010	0.030	0.000	-0.040	-0.100	0.030	-0.060	0.040	-0.060	-0.040
0.060	0.290	0.080	0.020	0.000	0.020	0.160	0.010	0.070	0.090	0.060	0.060
-0.080	0.010	0.020	0.080	0.070	0.040	0.010	-0.020	0.000	0.000	-0.010	0.000
0.010	0.060	0.070	0.080	0.000	-0.010	0.020	0.000	0.020	0.020	0.010	0.000
-0.010	0.000	0.000	0.000	0.040	0.110	-0.040	-0.090	0.030	0.020	0.020	0.000
0.010	0.000	0.020	0.040	0.160	0.070	0.000	-0.080	0.010	-0.010	0.000	0.070
S211	S213	S222	S231	S233	S242	S251	S253	S262	S271	S273	S282
1849	1850	1850	1850	1850	1850	1849	1849	1849	1851	1850	1850
0.050	0.000	0.290	0.060	0.020	-0.010	0.020	0.000	-0.010	0.000	-0.050	-0.160
0.250	0.040	0.050	0.100	0.020	0.000	0.110	0.000	-0.010	0.020	0.100	0.080
0.200	-0.020	0.120	0.000	0.060	0.010	-0.040	0.000	0.100	0.060	-0.020	0.010
0.280	0.130	0.050	0.060	0.050	0.070	0.010	0.020	-0.030	-0.020	-0.060	0.000
0.190	-0.010	0.040	0.000	0.000	-0.150	-0.040	-0.090	-0.080	0.330	0.050	-0.140
0.090	0.010	0.110	0.000	-0.030	-0.060	-0.010	0.080	0.000	-0.010	0.030	-0.020
0.150	0.020	0.080	0.060	-0.010	0.010	0.050	0.090	0.010	0.030	0.050	0.110
0.210	-0.020	0.040	-0.120	0.050	0.010	0.000	0.000	-0.120	0.020	0.020	-0.020
S311	S321	S331	S341	S351	S361	S371	S381	Action Menu			
1850	1850	1850	1849	1850	1850	1849	1849	!	On		
0.010	0.170	0.100	-0.140	0.100	0.000	0.130	0.020		Off		
0.010	-0.030	0.020	0.070	0.030	0.030	0.230	0.130				
0.130	97.290	0.030	0.030	0.060	-0.010	0.860	0.070				
0.080	0.070	-0.030	0.040	0.000	-0.040	0.140	0.020				
0.000	-0.120	0.000	0.030	0.080	0.000	0.200	0.090				
0.030	-0.020	0.000	0.010	0.060	-0.010	0.090	0.110				
0.050	0.010	0.070	0.220	0.150	0.000	0.230	0.070				
0.070	-0.010	-0.040	0.100	0.070	0.050	0.200	0.170				

DIMUON CANDIDATE

3 stations of Muon Tracker

Dimuon candidate from
p+p collision (rotated for
clarity with beam line
running vertically)



2 muon candidates penetrate muon identifier panels